DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE AMONG SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY-KENYA

BY

CHARLES OKECH ODHIAMBO

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DECLARATION

I hereby declare that this thesis is my original work and has not been submitted to any other university for examination.

Sign .... **Date** ....

CHARLES OKECH ODHIAMBO

REG. No. PHD/AF/00131/2013

This thesis has been submitted for examination with our approval as University supervisors:

Sign .... **Date** ....

Prof. Harun O. Ogindo

Department of Applied Plant Sciences,

Maseno University

Sign .... **Date** ....

Dr. Chrilukovian B. Wasike

Department of Animal Science,

Maseno University

Sign .... **Date** ....

Dr. Washington O. Ochola

Africa Lead (USAID)

(Deceased)

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DEDICATION

I dedicate this Thesis to my Wife, Helida, and children; Tabitha, Emmanuel, Grace and Mercy. Let all of you know that my God can make me do all things, provided I keep my faith in Him (Matthew 19:26). If I have done this through God who gives me strength (Philippians 4:13), what can you not do in your might, yet the Lord is with you? (Judges 6: 12, 14, 16)

ABSTRACT

Climate change (CC) impedes Kenyan smallholder dairying. An understanding of climate changes and factors determining smallholder dairy farmers' CC adaptation could help sustain the industry in milk-deficient regions. This study sought to establish the factors that determine smallholder dairy farmers' CC adaptation in Migori County-Kenya. Specifically, it sought to assess the level of CC adaptation, the influence of socio-demographics on CC adaptation; and relationships between CC perceptions, knowledge and institutional support and adaptation among study respondents. Using *Concurrent Fixed Mixed Methods*, data was collected from 367 smallholder dairy farmers with at least 10 years' experience obtained by multi-stage sampling; while purposive sampling was used to pick qualitative study respondents. Binary logistic regression and *Framework* methods were used in analysing quantitative and qualitative data, respectively. Data from nearest meteorological station indicated a 0.3^{o}C increase in both day and night temperature (1982-2015)and about 195mm increase in annual rainfall(1982-2015), confirming respondents' perceptions. Respondents perceived CC had high impact on dairy cattle health (61.3%) and feed availability (43.6%), and moderate effect on labour requirements (43.6%). Adaptation practices included mixed farming (96.5%), non-intensive production (95.1%), using household labour (94.6%), reducing herd size to 2 (92.9%), establishing own fodder (92.4%), rearing cross-bred cattle (87.7%), mainly of non-Friesian blood and their crosses (87.5), and maintaining an increasing trend in income from milk sales (68.4%). Mixed farming, non-intensive production system, and own fodder were main adaptability determinants. Z-scores ($7.05<Z<17.82$; $p<0.05$) indicated significantly high adaptation level. Gender significantly influenced household labour use (Adjusted Odds=0.32; p=0.05); while household size significantly influenced adoption of own fodder (Adjusted Odds=0.70; p=0.00) and increasing dairy income trend (Adjusted Odds=0.82; p=n/a). Perceptions of decreased night temperatures significantly influenced mixed farming (Adjusted Odds=0.13; p=0.04) and rearing of non-Friesian breeds and their crosses (Adjusted Odds=0.19; p=0.01). Perceptions of no change in night temperatures significantly influenced rearing of non-Friesian breeds and their crosses (Adjusted Odds=0.08; p=0.02); and perceptions that distribution of short rains got worse significantly influenced adoption of own fodder (Adjusted Odds=0.02; p=0.01). Majority (61%) of respondents had above-average CC knowledge, with the total score greatly influencing dairy herd size (Adjusted Odds=0.11; p=0.02). Public extension services (50.4%), radio (38.1%) and television (15.3%) were most preferred CC information sources. The study concluded that CC has occurred in Migori, having moderate to high effects. Study respondents are well adapted; with farmers' socio-demographics, CC perceptions, knowledge, and institutional support positively influencing their CC adaptation. Governments should invest in climate forecasting infrastructure; support female farmers' adaptation; use radio, television and farmer-based extension approaches to pass climate information; and incorporate indigenous CC knowledge in CC adaption plans, strategies and policies.

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

AEZ	Agro Ecological Zone
AFC	Agricultural Finance Corporation
A.I	Artificial Insemination
ASDSP	Agriculture Sector Development Support Programme
ASK	Agricultural Society of Kenya
CBK	Central Bank of Kenya
CC	Climate Change
CCAFS	Climate Change, Agriculture and Food Security
CGFI	Centre for Global Food Issues
C.I	Confidence Interval
CIGI	The Centre for International Governance Innovation
C-MAD	Community Mobilization Against Desertification
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field School
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GHG	Green House Gas
GoK	Government of Kenya
HPI	Heifer Project International
ICARDA	International Centre for Agricultural Research in the Dry Areas
ICIPE	International Centre for Insect Physiology and Ecology
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
ITK	Indigenous Technical Knowledge
KAAA	Kenya Agribusiness and Agroindustry Alliance
KALRO	Kenya Agricultural and Livestock Research Organization
KCB	Kenya Commercial Bank
KDB	Kenya Dairy Board
KDDP	Kenya Dairy Development Programme
KENTTEC	Kenya Tsetse and Trypanosomiasis Eradication Campaign

KF-LDP	Kenya Finland-Livestock Development Programme
KII	Key Informant Interview
K-REP	Kenya Rural Enterprise Programme
KWFT	Kenya Women Finance Trust
LBDA	Lake Basin Development Authority
LM	Lower Midland
Ltd.	Limited
LVOS	Lake Victoria Observation System
MFIs	Micro Finance Institutions
MoA	Ministry of Agriculture
MoALFD	Ministry of Agriculture, Livestock and Fisheries Development
NACOSTI	National Commission for Science, Technology and Innovations
NALEP	National Agriculture and Livestock Extension Programme
NDDP	National Dairy Development Programme
NEP	National Extension Project
NGOs	Non-Governmental Organizations
PCA	Principal Component Analysis
PCs	Personal Computers
PDA	Personal Digital Assistant
SD	Standard Deviation
SDCP	Smallholder Dairy Commercialization Project
SDDP	Smallholder Dairy Development Project
SDP	Smallholder Dairy Project
SNCDP	South Nyanza Community Development Programme
TV	Television
UHT	Ultra Heat Treated
UM	Upper Midland
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WWEC	West Wales Eco Centre

DEFINITION OF TERMS

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2014). In this study, it is looked at the response of the smallholder farmers to climate change effects.

Adaptive Capacities: Ability to see, understand, and influence patterns in human systems. In this study, it will be viewed as the set of skills, abilities and practices that should help to build resilience among smallholder dairy farmers to the negative effects of climate change within the ecosystem of study.

Adaptive Strategies: The specific measures (or actions) that smallholder dairy farmers might take in order to minimise the consequences and impacts of climate change on the performance of the dairy industry in Migori County, thereby maintaining productivity and profitability of the smallholder dairy industry and without causing harm to the biotic and/or abiotic environment that may further exacerbate the effects of climate change either locally, regionally or globally. In this study the strategies include: breeds of dairy cows kept, production method adopted, number of dairy cows kept, farming types chosen, and level of labour investment (whether self, family, hired/casual or skilled).

Adoption: A change in practice or technology used by economic agents, or a community.

Climate Change: Is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events). In this study, changes in rainfall pattern will be construed as climate change.

Climate Change Effects: The potential future effects of global climate change including more frequent wildfires, longer periods of drought in some regions and an increase in the number, duration and intensity of tropical storms.

Communication channel: The means by which messages get from one individual to another.

Crossbred Cattle: Cattle whose parents are of two different breeds, such as Friesian and Ayshire or Ayrshire and Guernsey.

Diffusion: The process by which an innovation is communicated through certain channels over time among the members of a social system.

Friesian: This is one of the cattle breeds primarily raised for milk production, hence; is a dairy cattle breed. The breed, also known as Holstein Friesian, originated from Northern Netherlands (Friesland Province) and was further developed in Northern Germany. It is characterised by black and white colouration, adapted to very cold areas, and produces the highest amount of milk among all the dairy cattle breeds. Nevertheless, it has the highest feed demand, and is highly vulnerable to weather changes, parasites and diseases.

Global Warming: This refers to an unequivocal and continuing rise in the average temperature of Earth's climate system.

Hard adaptation: Involves some form of construction (Bebe, 2013), e.g. of a zero grazing unit, feeding trough, etc.

Household: People who live under the same dwelling unit, share living space, cook and eat from the same pot. In this study, the farmer, his family members, workers, and other relatives that dwell together and eat together under the same roof constituted the household, whose size was subject of investigation in thestudy.

Innovation: An idea, practice, or object that is perceived as new by an individual or other unit of adoption. It may also be looked as a technology.

Institutions providing farmer support: The terminology is used in this study to refer to all the support that smallholder dairy farmers receive from the public, private, state and non-state actors to enable them cope better with the effects of climate change. The range of support may vary from information, training, financial to material support.

Institutional support: The study viewed dairy farming units as institutions, with climate information channels, sources, systems, policies, and structures being viewed as support to the same.

Knowledge: The sum of what has been learned or discovered from both teaching or personal reading and discovery. It is what a smallholder dairy farmer knows regarding climate change effects.

Non-Friesian breeds: Used in this study to refer to all the exotic dairy cattle breeds except Friesian, which is considered less adaptable to climate changes, diseases and parasites; and requires intensive rearing with high labour demand.

Perception: An interpretation, impression, opinion or belief held by a person. In this study it was used to refer to the awareness, comprehension or understanding that the smallholder dairy farmers had of climatic changes (particularly with regard to temperature and precipitation) taking place in the study area.

Resilience: The ability of a community to resist, absorb, and recover from the effects of hazards in a timely and efficient manner, preserving or restoring its essential basic structures, functions and identity (CARE, 2009). It is a concept very commonly used in the context of disaster.

Smallholder Dairy Farmer: A farmer who specializes in raising livestock for purposes of producing milk, but on a small-scale. In most cases the limitation comes in with respect to the size of the farm as well as the number of dairy animals kept, often forcing the farmer to venture into some other supplementary type of farming in order to keep the enterprise afloat.

Most smallholder dairy farmers in the developing world are mixed farmers-growing crops and raising livestock for both domestic and commercial purposes. In this study, these are farmers whose land-holdings are 3-5 acres, and who use all or part of it for dairy production from either cattle, goats or a mix of the two.

Socio-demographic characteristics: Smallholder dairy farmers' characteristics, such as; age, sex, education, marital status, household size, employment status, income level, religious affiliation, etc. In this study, six (6) socio-demographic characteristics of the smallholder dairy farmers studied included age, sex, highest education level, marital status, household size, and experience in dairying.

Soft adaptation: Involves capacity building (Bebe, 2013). Establishing own fodder, use of household members to provide farm labour, and choosing the right breed of dairy cattle to rear, adopting mixed farming, as well as experiencing an increasing trend in income from milk sales; could all qualify as soft adaption, especially if the farmers adopt them after undergoing some form of training.

Sustainability: Meeting the current needs without compromising the ability of the future generations to meet their own needs. These would include natural, environmental, social and economic needs. In this context the terminology was used to mean smallholder dairy farmers being able to provide the immediate milk needs of the country and be able to do so going forward, despite the climate change effects in their localities.

Technology: An innovation. The terminology is used here to mean climate change adaptive strategies that smallholder dairy farmers adopt to cope with climate change effects.

Technology Adoption: The acceptance, integration, and use of new technology in society. It is used in this study to refer to the process by which smallholder dairy farmers would accept, integrate and make use of climate change adaptive technologies in order to cope with climate change effects.

Two dairy cattle and above: Used in this study to refer to two milking dairy cows and a heifer, two milking dairy cattle and a calf, two milking dairy cows and a bull or two milking dairy cows and a bull calf.

Vulnerability: "The degree to which a system is susceptible to harm due to exposure to stress and the ability (or lack thereof) of the exposure unit to cope, recover, or fundamentally adapt-i.e. become a new system or become extinct" (Kasperson *et al.,* 2000; cited by UNDP, 2005, p. 250). The vulnerability of a system is influenced by the adaptive capacity of its people and institutions, or their ability to take advantage of opportunities or to cope with the consequences of potential damages (IPCC, 2001). In this study it refers to the extent to which smallholder dairy farmers and the dairying enterprise are exposed to harm caused by the effects of climate change; herein perceived to be high owing to their low adaptive capacity.

LIST OF TABLES

FIGURES

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Worldwide, livestock production takes 77% of all land used for agriculture (Ritchie & Roser, 2019)with 14.5% of anthropogenic greenhouse gas emissions (methane, nitrous oxide, and carbon dioxide) being attributed to the livestock sector(Rojas-Downing *et al.*, 2017; CGIAR, 2020).Studies by Ludi (2009) and Harvey et al (2018) indicates that there is a strong link between food security, climate change, water scarcity and poverty; with poverty being seen to be both a driver and a result of food security. This complicates efforts to design effective programmes to address food security, climate change, and water scarcity. Nevertheless, by introducing agriculture into the equation, this now becomes feasibleas demonstrated by Smit & Pilifosova (2018), but the gap is how to make agriculture sustainable in the wake of global challenges, such as climate change.

Whereas there is overwhelming evidence demonstrating that climate change is a serious global issue that demands an urgent global response (Stern, 2006), global efforts to address climate change effects are not commensurate to the demonstrated effects on people's access to water, food production, health; as well as the environment (Sivaramanan, 2015).As a result, most countries are increasingly becoming prone to droughts and floods, with rural farming practices, deforestation and charcoal production having a dramatic impact on severity of floods (Harvey *et al*., 2018; Steiner *etal*., 2020). Coping with climate change effects, especially among smallholder farmers, remains a great challengeand needs the attention of donors, governments, policy makers, planners, and local communities (UNISDR, 2012).

Owing to low investments in dairying, illiteracy, poor infrastructure, low government support, poor access to credit facilities, and inflexible policies, among others; smallholder dairying is highly vulnerable to climate change compared to large scale dairy production systems (Muriuki, 2003; Kibogy, 2019). Therefore, unreliable precipitation patterns lead to declining livestock productionamong smallholder dairying systems (FAO, 2008; Sirohi & Pandey, 2010; FAO, 2020); yet there is little involvement by governments and stakeholders to supportvigorous environment and climate change adaptation measures, use of new practice and technologies, and policies and financing(Smit & Pilifosova 2018; CGIAR, 2020; Steiner *etal*., 2020).

Ironically, Africa that contributes the least to global warming, suffers greatest loss as a result of climate change, largely owing to its high vulnerability, low adaptive capacity, heavy dependence on rain-fed agriculture, cultivating marginal areas, lack of access to technical or financial support and high poverty levels (Elum *et al*., 2017; Harvey *et al*., 2018; UNEP, 2019).Whereas Africa's 54 countries boast of a large number of dairy cattle of about 49 million dairy cows; majority of these are in Ethiopia, Kenya, South Africa and Sudan. While South Africa produces most of the milk per cow, only Ethiopia and Kenya are self-sufficient in milk and dairy products (Dolecheck & Bewley, 2015). Thus, there is no doubt that dairy production in the Sub-Saharan Africa is predominantly smallholder, making up to 80% of the total dairy producers (Dolecheck & Bewley, 2015; Odero –Waitituh, 2017). These smallholder dairy farmers in Sub-Saharan Africa are the most vulnerable to climate change effects. Despite this, most climate change adaptation studies in Africa have tended to consider adaptation of smallholders who major in crop production, and only divest into rearing of local cattle in the face of climate change (Bagamba *et al*., 2012; Babatolu *et al*., 2016; Chepkoech *et al*., 2018).

In Kenya, over 80% of the domestic milk comes from the smallholder dairy systems (TechnoServe Kenya, 2008; 3R Kenya Project, 2020).Bebe (2003) argues that these systems contribute directly and indirectly to increased livestock population and farm productivity, with TechnoServe Kenya (2008) and KAAA (2016) adding that smallholder dairying in Kenya contributes to income generation from milk and dairy product sales, job opportunities, and the transfer of money from urban to peri-urban and rural areas. Nevertheless, smallholder dairy farmers in Kenya have not intensified rearing of high quality breeds, thereby compromising productivity (Odero –Waitituh, 2017). Instead, Kenyan smallholder dairy farmers rear a mix of exotic breeds and crosses between exotic and local breeds and local breeds used for milk production(Dolecheck & Bewley, 2015).

Most of the exotic dairy blood in Kenya is of Friesian, Guernsey, Ayrshire, Jersey, and their crosses (Kibogy, 2019), depending largely on the ecosystem and the level of financial investment. Even where the smallholder dairy farmers rear high quality exotic breeds, the same are often reared under a mix ofextensive and semi-intensive methods that greatly compromise their production, hence returns (Reynolds *et al*., 1996;Wilkes *et al*., 2020).While Muriuki, (2003) and FAO (2020) cite diminishing land sizes, ever-increasing costs of agro-inputs, and high illiteracy and poverty levels as the main reasons for Kenyan smallholder dairy farmers adopting poor production methods that lead to low yields, TechnoServe Kenya (2008); Huho*et al*. (2011) and Odero-Waitituh, (2017) add challenges of limited extension services, non-responsive government price regulatory policies, emergence of resistant strains of pests and diseases, and pre-and post-harvest losses leading to low financial returns on production. Yet, these challenges are nothing compared to the challenge posed by global warming and the associated climate change, which is negatively affecting productivity in smallholder farming systems; leading to declining food production trends in the recent decades in spite of the increasing human population (Lisk, 2009; Bebe, 2013;Rojas-Downing *et al.*, 2017).

With climate change and the ever-diminishing land sizes, the farmers are under pressure to intensify production (Clay, Garnett & Lorimer, 2020), yet this contributes further to depletion of ozone layer (FAO, 2020; Steiner *etal*., 2020), and, thus; is not sustainable (Bebe, 2003). This is, therefore, an urgent need to improve smallholder dairy farmers'access to viable, farmer-friendly, cheap, adaptable and practical ways to mitigate and/or adapt to climate change without compromising future socio-economic and environmental benefits (Osman-Elasha, 2009; Vogel, 2015; Mashizha, 2019).

Since mitigation will take time to bear fruits, it would be more feasible to invest in smallholder dairy farmers' climate change adaptation to improve production and income earnings(KAAA, 2016; Harvey *et al*., 2018).Climate change adaptation could take the form of soft or hard adaptation, with the goal of ensuring the farmers provide the food security and income needs of the households and the nation, and; above all, remain sustainable in the dairy industry, while not compromising the environmental and future needs of the society through increased greenhouse gas (GHG) effects (Bebe, 2003). How to empower the smallholder dairy farmers to effectively and efficiently achieve this is the main challenge facing governments and stakeholders.

Smallholder dairy farmers have a compendium of adaptive practices to choose from, depending on their level of education, exposure to climate change information, support from governments and stakeholders, level of infrastructural development, and existing policies

(Osman-Elasha, 2009; Chepkoech *et al*., 2018). Such practices would include; practicing mixed dairy and crop farming, rearing the dairy herd under semi-intensive production system, establishing own fodder in line with the number of dairy cattle and their feeding demand, rearing cross-bred instead of pure breed cattle, rearing locally adaptable breeds of dairy cattle, reducing the herd size to a manageable and yet sustainable number that would enable farmers to break-even, and reducing farm labour demand by relying on household labour(Bagamba *et al*., 2012; Banerjee, 2015; Bosire et al., 2019). Whereas such climate change adaptive practices could be used to measure climate change adaptation by smallholder dairy farmers, the ultimate measure of smallholder dairy farmers' adaptability to climate change effects would be an increasing trend in income earned from milk sales(Davis & Place, 2003; Prokopy *et al*., 2017). Thus, if having done all to adapt to climate change effects, the smallholder dairy farmer is unable to realize an increasing trend in income earning from milk sale, the venture is unsustainable, and the future of the enterprise is in jeopardy.

While the government's role is to enact policies and provide an enabling institutional framework for supporting climate change mitigation and adaptation (Osman-Elasha, 2009; Welborn, 2018; Mashiza, 2019), extension services plays a critical role in supporting smallholder dairy farmers to gain access to information on new technologies for adapting to climate change effects (Mwangi, 1998; FAO, 2017). These include increased technological investment in milk production to lower production costs, efficient management of dairy intensification to improve production while reducing GHG emission, improved breed selection, improved productivity through improved feeding and health care, and improved general management (Somda *et al*., 2004;Sirohi & Pandey, 2010; Steiner *etal*., 2020). Yet the extension services in Kenya, as in most countries in the tropics, has poorly remunerated and facilitated officers, who are low in numbers, demoralized, and unable to meet the farmers' needs (Davis & Place, 2003; Dehinenet *et al*., 2014; De Janvry *et al*., 2016).

Owing to inefficient government extension system, therefore, smallholder dairy farmers in Kenya have to obtain vital climate change information from other sources; including fellow farmers, mass and print media, research and academic institutions (Chepkoech *et al.,* 2018; Jairo & Korir, 2019; GEF, 2020). The climate change information sources not being uniform then, could bring differences in smallholder dairy farmers' climate change adaptation. Yet, this would not be the sole determinant of smallholder dairy farmers' climate change adaptation. Studies by Harvey *et al*. (2018) and Chepkoech *et al*. (2018) suggest that farmers' socio-demographic profile, their perceptions and knowledge of climate change and its effects on dairying would greatly determine how smallholder dairy farmers would adapt to climate change effects. The factors that determine smallholder dairy farmers' climate change adaptation would vary from one area and community to another, making an understanding of local adaptation very essential. Yet local climate change adaptation data and the factors that determine smallholder dairy farmers' adaptability to climate change effects, and the gaps that need to be addressed in order to improve their resilience to climate-change is either rare or totally lacking. This makes it difficult for the Government and stakeholders to adequately support the Kenyan smallholder dairy farmers in their climate change adaptation efforts(Kirui *et al*., 2015; Harvey *et al*., 2018).

Secondary data obtained from Migori County Livestock Office indicates that the county is milk deficient (GoK, 2019b), having to import milk from neighbouring counties (Table 4; Abayomi, 2013; GoK 2019b) despite suitable weather conditions. Climate change is partly blamed for thistrend (GoK, 2019b). While the study by Simotwo *et al* (2018) attempted to assess the climate change adaptive capacity of smallholder farmers in South western Kenya, it was in a pastoral context and not among the dairy farming community, hence; need to understand the capacity of smallholder dairy farmers to climate change effects.

1.2 Statement of the Problem

Climate change poses probably one of the greatest threats to the sustainability of smallholder dairy farming systems in Kenya, with the farmers being highly vulnerable, yet their adaptive capacity is low. In Migori County, in particular, despite high potential and suitable weather for dairying, the County is milk deficient, having to import milk from neigbouring counties in order to meet local milk demand. Smallholder dairy farmers in Migori County grapple with how to increase and sustain milk production and income earnings from milk sales in the wake of climate change. Since climate change effects transcend county and national boundaries, it would be important to invest more in enhancing smallholder dairy farmers' adaptive capacity rather than on mitigation measures. This would require a clear understanding of the climatic changes that have occurred in an area, the extent to which the changes affect smallholder dairying, the farmers' response to the effects, and what determines the nature and scope of the responses adopted. This requires empirical data that is specific to a locality, but which could be extrapolated to a larger region within a similar context. Against this backdrop, this study endeavoured to assess climatic changes in Migori County, their effects on smallholder dairying, farmers' adaptive responses (or strategies), and the factors that determine the adaptive responses employed. This would greatly support the County in its efforts to improve its milk production and bridge the deficit that has been experienced for some time. It would also help Kenya and other tropical nations in Africa in enhancing the smallholder dairy farmers' capacity to prevent, manage and recover from disasters and adapt to the impacts of climate change, thereby spurring sustainable development locally, regionally, and globally.

1.3 Study Objectives

1.3.1 General Objective

This study sought to establish the factors that determine smallholder dairy farmers' climate change adaptation in Migori County.

1.3.2 Specific objectives

In line with the general objective, the study had five specific objectives, namely:

1. To assess the level of adaptation to climate change among smallholder dairy farmers of Migori County-Kenya.
2. To establish the influence of socio-demographic characteristics of smallholder dairy farmers of Migori County-Kenya on their climate change adaptation.
3. To establish the relationship between smallholder dairy farmers of Migori County-Kenya's climate change perceptions and climate change adaptation.
4. To establish the relationship between climate change knowledge of smallholder dairy farmers of Migori County-Kenya and their climate change adaptation.
5. To establish the relationship between smallholder dairy farmers of Migori County-Kenya's institutional support and climate change adaptation.

1.4 Study Hypotheses

The study hypotheses were linked to each of the specific study objectives. For each objective, the null hypothesis was stated as follows:

H_{o1}: Level of adaptation to climate change among Smallholder dairy farmers of Migori County-Kenya is not statistically significantly high.

H_{o2}: Socio-demographic characteristics of Smallholder dairy farmers of Migori County-Kenya has no statistically significant influence on their climate change adaptation.

H_{o3}: There is no statistically significant relationship between climate change perceptions of Smallholder dairy farmers of Migori County-Kenya and climate change adaptation.

H_{o4}:There is no statistically significant relationship between climate change knowledge of Smallholder dairy farmers of Migori County-Kenya and their climate change adaptation.

H_{o5}:There is no statistically significant relationship between Smallholder dairy farmers of Migori County-Kenya's institutional support and climate change adaptation.

1.5 Scope and Limitations of the Study

In terms of geographical scope, the study was conducted in Migori County in South-western part of Kenya. The County has sixAgro-Ecological Zones (AEZ), ranging from Upper Midland (UM) $_{1\text{-}4}$ to Lower Midland (LM) $_{1\text{-}5}$. Nevertheless, based on temperatures and rainfall patterns, Migori Countyhas been sub-divided into three (3) distinct zones (Western, Central and Eastern). This study was confined to the Central Zone, covering UM_2 (in Rongo) and $LM_{2,}$ in Awendo, Uriri, and Kuria West sub-counties. The four sub-counties, together with Suna East (not covered by the study for its largely cosmopolitan nature) are also the dairy belt of the County.

This cross-sectional correlational study considered the level of adoption of climate change adaptive strategies by the study respondents; the socio-demographic profile, perceptions and knowledge of smallholder dairy farmers of Migori County-Kenya, and their sources of information regarding climate change, as well as the relationships between these and the climate change adaptation by the respondents. The study, however, did not assess the extent of inter-factor relationships and its influence on climate change adaptation among the respondents.

The study adopted *Concurrent Fixed Mixed* approaches for data collection and analysis, with equal weight being given to both quantitative and qualitative data; with a view to generating rich qualitative data to validate the quantitative findings. Data collection involved review of secondary data obtained using a secondary data collection checklist. The data was mainly obtained from government offices, research findings published in refereed journals, conference proceedings, papers presented in workshops and climatic data from a meteorological station within Migori County. Primary data collection tools included household survey questionnaire, key informant interview guide, focus group discussion guide, and observation guide.

1.6 Assumptions

i. That each of the study respondents had an equal chance of getting access to climate change information from all the available sources.
ii. That each of the study respondents had an equal access to support from all institutions and stakeholders.
iii. That each of the study respondents enjoyed general security, peace and tranquillity at the time of undertaking the study.
iv. That there was little or no diffusion of information between the pre-test respondents and the study respondents.

1.7 Significance of the study

The study sought to provide a basis for understanding and describing the climate change effects on the general performance of the smallholder dairy industry in Kenya, the level of adaptation of the smallholder dairy farmers to climate change effects, and the factors that determine the adaptive practices the farmers opt for in order to adapt and remain sustainable in the dairy industry in the midst of climate change that is a global phenomenon. The study, therefore, adds to the wealth of existing literature for researchers, extension agents and policy makers on the adaptive strategies of Kenya's smallholder dairy farmers to climate change effects.

Migori County in South-western Kenya was chosen for the study on the basis of several factors. First, despite Kenya being self-reliant in milk and milk products (Dolecheck & Bewley, 2015; Wilkes *et al*., 2020), Migori County is one of those counties in Kenya that suffers a milk deficit and has to import milk from neighbouring counties to meet the gap (Table 4; Abayomi, 2013; GoK, 2019b). Secondly; available literature on smallholder dairy farmers' adaptation to climate change effects pointed to the fact that some work has been done in the Coastal, and highland regions of Kenya-i.e. Central and Eastern parts (Mwaniki, 2016; Wamugi, 2016; Mutunga*et al*., 2017), but very little had been done in South-western region that makes a significant contribution to Kenya's smallholder dairy industry. In fact, this is the first of such study on the adaptation of smallholder dairy farmers of South-western Kenya. Moreover, Migori County is unique in that it has six (6) different Agro-Ecological Zones, ranging from Upper Midland (UM) $_{1-4}$ to Lower Midland (LM) $_{1-5}$, hence; representative of a cross-section of Kenya's dairy production zones. The study, however, limited itself only to UM_2 and LM_2, which are representative of marginal areas of Kenya, hence; there is still potential to conduct further studies across the other Agro-Ecological Zones of Migori County.

The study findings would, hence; be useful to researchers for understanding and replication. To the policy makers, both at the national and county government levels in Kenya, study findings would be useful in formulating climate change adaptation policies, plans and strategies. And, to extension agents and smallholder dairy farmers of Kenya's marginal areas, study findings would be useful for understanding and planning as a vital source of information for improving smallholder dairy farmers' adaptation to climate change effects. The study would also be useful to other developing countries across the tropical world in improving their adaptation to climate change effects.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this Chapter, the major literature that informed this study are reviewed. Section 2.2 gives an overview of dairy production in Kenya, highlighting the role of large scale and smallholder dairy systems to the Kenyan Dairy Sector. Section 2.2 also highlights smallholder dairy farming in South-western Kenya, and ends with challenges and opportunities in the Kenyan Dairy Sector. Section 2.3 describes climate change and its effect on dairy production in Kenya.

Section 2.4 describes the global adaptive strategies of the dairy industry to climate change impacts, while Section 2.5 describes the factors that influence producers' adaptation to climate change; including Gender, Age, Marital status, Level of education, Household size, Experience in dairying, Farmers' perceptions to climate change and Farmers' knowledge of climate change effects on dairying. Section 2.6 describes the role of institutions and extension services in mitigating effects of climate change in dairy systems. Section 2.7 provides a summary of the literature reviewed and identified gaps. Section 2.8 describes the Theoretical Framework upon which this study was built, while Section 2.9 describes the study's Conceptual Framework.

2.2 Dairy production in Kenya

Kenyan dairy sub-sector contributes about 8% of the national GDP, producing about 3.43 billion litres of milk annually from 4.3 million dairy cattle (Abayomi, 2013; Kibogy, 2019). The dairy cattle include exotic breeds (*Bos taurus*), crossbred cattle, and indigenous cattle (*Bos indicus*). Rearing methods range from intensive to semi-intensive, and to extensive

(Odero-Waitituh, 2017). In spite of 80% of Kenyan dairy being small-scale dairy farmers and with a great growth pitentail (TechnoServe Kenya, 2008; 3R Kenya Project, 2020), smallholder dairy industry in Kenya is under-developed compared to large scale commercial dairy production (Kobogy, 2019).

Large-scale dairy systems in Kenya are mainly found within the Kenyan highlands, Kiambu-Nairobi area, and the Rift Valley, within Agro-Ecological Zones 1-3 (AEZ 1-3) with bimodal rainfall that support growth of high quality forages and pasture that sustain the dairy industry (Der Lee*et al*., 2016). The systems are characterized by large land sizes, high levels of capital investment, mechanized production, intensification, high livestock management levels, use of mainly commercial feeds, and organized milk-marketing system (Muriuki, 2003; Abayomi, 2013; Der Lee*et al*., 2016). Majority of the large-scale dairy farming systems are privately owned, and operate a "solely livestock" system, with a highly organized milk marketing system (Der Lee*et al*., 2016). Smallholder dairying in Kenya on the other hand, is practiced in parts of the highlands of Central, Eastern Region, Rift Valley Region, Western and Coastal regions and with small land sizes, low capital investments, largely human labour, poor livestock management levels, use of roughages and minimal supplementation, with poorly organized milk marketing systems (TechnoServe Kenya, 2008; Der Lee*et al*., 2016). Despite the glaring gaps and challenges facing the smallholder dairy production systems in Kenya, several studies in Kenya have covered large scale dairy farming households, with those covering smallholder dairy farmers doing so among farmers in Central Kenyan highlands, Eastern and Coastal regions (Mwaniki, 2016; Mutunga *et al*., 2017; Jairo & Korir, 2019). Thus; minimal studies have been conducted among smallholder dairy farming households Western Kenya, particularly south-western part of Kenya (Simotwo *et al*., 2018).

Smallholder dairy production systems in Kenya are characterized by mixed crop-and livestock farming, semi-intensive or extensive production, small land holdings, low capital investment, low milk production, poorly organized milk marketing, and low use of commercial feeds (TechnoServe Kenya, 2008; Odero-Waitituh, 2017). Smallholder dairy production systems in Kenya are concentrated within AEZ 3-4 (TechnoServe Kenya, 2008; Der Lee*et al*., 2016) and feeds include natural grass, planted fodder (like Napier grass); and sometimes maize stover, compounded feeds, and milling by products (like maize and wheat brans and germ, cotton and sunflower seedcakes, molasses, etc.). The dairy animals are tethered and at times fed in stalls (Kibogy, 2019; Wilkes *et al*., 2020). Use of Artificial Insemination (A.I) depends on its cost and availability; otherwise, bull camps are used for reproduction (Muriuki, 2003). Smallholder dairy systems in Kenya are rapidly expanding due to favourable climate, high number of dairy cattle, high demand for dairy products by the rapidly growing urban population, rapid infrastructural development, and a favourable government policy and institutional arrangement (Muriuki, 2003; TechnoServe Kenya, 2008; Odero-Waitituh, 2017), albeit faced with several challenges (Huho*et al*., 2011; KAAA, 2016; Rojas-Downing *et al.*, 2017). Climate change by and large remains the greatest challenge as it transcends national and regional boundaries, agro-ecological regions and socio-cultural confines (Lisk, 2009).

2.2.1 Contribution of large-scale dairy systems to the Kenyan dairy sector

Kenya’s annual milk production is 3.43 billion litres (Abayomi, 2013; Kibogy, 2019). Only about 15% of this is marketed thought milk processing outlets, implying that the bulk of the milk reaches the consumers through informal market, and in unprocessed state (TechnoServe Kenya, 2008; Abayomi, 2013; Kibogy, 2019). Large-scale dairy systems in Kenya make a great contribution to the dairy industry, producing 17-19 litres of milk per cow per day on average; most of which find its way to the milk processing outlets (Odero-Waitituh, 2017). The bulk of the processed milk and milk products, like pasteurized milk, ultra-heat treated (UHT) long life milk, cultured milk (*mala* and yoghurt), cheese, butter, ghee and milk powder, therefore; come from large scale dairy production systems. This is largely because of its organized milk marketing systems (Der Lee*et al*., 2016). Kenya is known to be largely self-reliant in milk and dairy products under favourable weather condition, with much of the dairy products in Kenya being consumed in the form of liquid milk in both urban and rural areas (Muriuki, 2003; Kibogy, 2019). Despite the fact that most of the 1.8 million dairy farmers are smallholder, large-scale dairy systems employ the bulk of the 1.2 million people estimated to find employment within the dairy sub-sector (Der Lee*et al*., 2016; Kibogy, 2019), meaning that smallholder dairying has a great potential to be supported by governments and other stakeholders to grow by increasing milk production and income earnings, and provide more employment opportunities (Osman-Elasha, 2009; Welborn, 2018; Mashiza, 2019).

2.2.2 Contribution of smallholder dairy systems to the Kenyan dairy sector

Smallholder dairy systems in Kenya dominate the dairy sub-sector, owning 80% of the 3.3 million dairy cattle and producing about 56% of total milk production (Muriuki, 2003; Abayomi, 2013). It also owns about 30-80% of the marketed milk (Bebe, 2003; TechnoServe Kenya, 2008). The dairy sub-sector contributes about 33% of the agricultural GDP, much of which contribution is from the smallholder dairy systems (Reynolds et al., 1996; Kibogy, 2019). Smallholder dairy systems in Kenya are characterized by crossbred dairy cattle, about 1-3 in number; kept alongside crops on the same farm that is usually a few acres (Reynolds et al, 1996; Wilkes *et al*., 2020). In this kind of arrangement, the smallholder dairy systems contribute directly and indirectly to increased livestock population and farm productivity, income generation from milk and dairy product sales, job opportunities, and the transfer of money from urban to peri-urban and rural areas (TechnoServe Kenya, 2008; Abayomi, 2013; FAO, 2020).Yet the attention being given to the smallholder dairy farmers by the government and stakeholders is not adequate to make meaningful and sustainable improvements in the Kenyan smallholder dairy industry (CGFI, 2000; FAO, 2017).

The Kenyan dairy sub-sector is estimated to produce about 2 million tonnes of milk annually from dairy cattle, the bulk of which is from smallholder dairy systems, with an average daily production of 5-8 litres per cow (Der Lee *et al*., 2016; Kibogy, 2019).

Other than milk production, smallholder dairy systems compliment crop production enterprise through traction and manure (Bebe, 2003). The manure produced is very useful in nutrient recycling and improves crop yields. Smallholder dairy farming is also practiced for food security, spreading of risks, and as a means to accumulate capital assets for emergency cash needs (Bebe, 1997; Bebe, 2003; TechnoServe Kenya, 2008). The systems provide 29%-94% of the total farm income, depending on the production system (Bebe, 2003; TechnoServe Kenya, 2008; Abayomi, 2013). For these reasons, smallholder dairy systems in Kenya deserve to be given greater attention by governments and stakeholders, yet this is not the case.

About 40% of the milk produced is consumed on-farm (mainly as raw milk after boiling), with the remaining 60% finding its way into the market through various channels, but less than 15% is channelled through milk processors (TechnoServe Kenya, 2008; Kibogy, 2019). Smallholder dairy production systems strive to increase milk production to meet the increasing demands by the ever-growing urban population due to rural-urban migration. To meet the household food and income needs, and sustain their livelihood base, smallholder dairy farmers must strive to strike a balance between increasing milk production and reducing production costs, while also reducing production of greenhouse gases (GHGs) and other environmental impacts (Der Lee*et al*., 2016; Clay*et al*., 2020; FAO, 2020). This is a task that the smallholder dairy farmers cannot undertake successfully on their own. Rather, they need the support of the government and stakeholders (Welborn, 2018; Mashiza, 2019). Nevertheless, governments and stakeholders also require a lot of data on smallholder dairy farmers, their climate change adaptation, factors determining that and gaps that require urgent attention; for them to adequately support the smallholder dairy farmers. This data is often inadequate if not completely lacking.

2.2.3 Smallholder Dairy Farming in South-western Kenya

South western Kenya, which is in in Kenya's Lake Region (formerly Nyanza Province), is one of the eight (8) regions that were initially known as provinces under the former constitutional dispensation before 2010. Then, it was called Nyanza Province, with its headquarters in Kisumu Town-now a Millennium City set to host Afri-Cities 2021. Lake Region comprises six (6) counties, namely; Siaya, Kisumu, Kisii, Nyamira, Migori and Homa Bay. The region borders Western and Rift Valley regions to the North and East, and Tanzania and Uganda to the South and West, respectively. It is inhabited by four major tribes, the Luos, Kisii, Suba and Kuria. It has a population of 5,442,711 (2009 census), and an area of 16,162 km^2; of which 3,684.9 km^2 is under water(GoK, 2014; GoK, 2019).There is no doubt that the region is a regional hub for East African Community, with a high human population; yet minimal studies, especially of smallholder dairy farming have been done in this region.

People living along Lake Victoria depend on agriculture-crop production, fishing and livestock; which are sensitive to climate change and variability.Free range cattle keeping is common, although smallholder dairy industry has a great potential and has shown tremendous improvement over the years in the region; despite challenges of poor husbandry practices, unpredictable rainfall, high input costs, weak milk marketing channels, prevalence of animal diseases and parasites, poor access to credit services and low uptake of research (GoK, 2014).Despite this huge potential, the effort being made by the government and stakeholders to improve the smallholder dairy industry in this region is still low (Mashiza, 2019). An understanding of how climate change affects smallholder dairying and how adapted the farmers are to climate change could possibly help improve stakeholder participation and support to the dairy industry in this region.

2.2.4 Challenges and opportunities in the Kenyan dairy sector

The socio-economic role played by the dairy sub-sector in Kenya cannot be over-emphasized. Nevertheless, the sector, which is smallholder dominated; faces several challenges. Moran (2005); Pradel *et al*. (2005) and Odero-Waitituh (2017) cite diminishing farm sizes due to over-fragmentation of land as population grows and land sub-division continues, inadequate and low quality feeds that lower production of the otherwise genetically good breeds as the key challenges facing the sector. Bebe (2003); TechnoServe Kenya (2008) and KAAA (2016) add that low investment into the production system by smallholder dairy farmers, high cost of feeds and agro-inputs, poor animal health and general management, and low farmer contact with agricultural extension services also bedevil the system.

Due to privatization of A.I services, limited qualified A.I service providers and unreliability of bull services; challenges of long calving intervals and low animal genetics are increasingly manifesting (Odero-Waitituh, 2017). Other challenges include poorly developed milk marketing systems, compounded by poor infrastructure development, especially in rural areas, male-domination, and inadequate access to financial services; since often smallholder dairy farmers lack collaterals to enable them access credit facilities (TechnoServe Kenya, 2008; Abayomi, 2013; Kibogy, 2019). Chronic poverty and low education being typical of smallholder dairy farming systems, the system also faces challenges of inadequate appropriate scientific technologies for effective management. Scholars (Huho *et al*., 2011; KAAA, 2016; Kibogy, 2019) argue that this, coupled with globalization and liberalization of the milk market and effects of climate change, make matters worse for the smallholder dairy farmers.

It would therefore, be important to understand how smallholder dairy farmers tend to adapt to climate change effects in any given area, and the factors that determine that. This study considered adaptation of smallholder dairy farmers with respect to feeding, breed selection and adaptation and labour investments; among others. The study also considered the influence of smallholder dairy farmers' socio-demographic characteristics of gender, age, marital status, educational level, household size and farming experience on their climate change adaptation.

Whereas globalization presents itself as a challenge, on the other side it is an opportunity for the Kenyan dairy sub-sector to extend its milk market beyond its borders, only if production could be scaled up to sustain local demand and sell the surplus. Techno Serve Kenya (2008) and Kibogy (2019) assert that the government could also improve policy environment to enhance milk production and marketing, by providing farmer-incentives to dairying, training, registering, organizing and coordinating the informal milk marketing agencies; thereby enabling them to acquire a formal and legal recognition. Opportunities also exist for the government to partner with private organizations, research institutions and universities, to support smallholder dairy farmers to improve milk production, while reducing production costs through improved feed production, and ensuring environmental sustainability by reducing GHG emissions(Muriuki, 2003; Clay, Garnett & Lorimer, 2020). Framers and milk handlers could also be trained on hygiene and minimizing pre- and post-harvesting milk losses (Reynolds *et al*., 1996; TechnoServe Kenya, 2008; Odero-Waitituh, 2017).Yet the extent to which these opportunities could be tapped by governments and stakeholders depend a lot on the extent to which the existing gaps are identified, documented and shared for targeting, resource allocation, and coordination.

Therefore, it would be important to know which individuals, institutions, organizations and groups are providing support to which farmers, in what manner and in which region, for a coordinated climate change adaptation support to be mounted to smallholder dairy farmers. This study reviewed institutional support available to farmers and institutions, organizations, individuals and groups that provided climate change information and/or technical and material support to enable farmers better adapt to climate change; with a view to understanding whether institutional support has any relationship with climate change adaptation.

2.3 Climate change and its effect on dairy production in Kenya

2.3.1 Global Warming and the Associated Climate Change

USEPA (2006) defines global warming as the increase in the average measured temperature of the Earth's near-surface air and oceans since the mid-twentieth century and its projected continuation and the resultant climatic change, more probably due to human influence (anthropogenic causes) than natural cause. Global warming occurs when carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other greenhouse gases collect in the atmosphere and absorb sunlight and solar radiation that have bounced off the earth's surface (Sivaramanan, 2015). Under normal circumstances, such radiation escapes into the space. Nevertheless, these pollutants, with long half-lives, spanning between years to centuries, trap the heat, thereby causing a warming of the planet (Anup, 2015; Sivaramanan, 2015). This is known as greenhouse effect, which leads to global warming and climatic changes with adverse effects on the ecosystem (MacMillan, 2016). Whereas this is well documented and known among scientists, the farmers may not know much of the science behind it, yet are able to experience the long-term effects of global warming and the associated climate change.

This study reviewed over 30-year (1982-2015 for temperature and 1980-2013 for rainfall) climate data available at the nearest local meteorological station to show that there were in-deed, changes in temperature and precipitation in Migori County over the period. The focus then, was on the effects of the changes and the adaptability of smallholder dairy farmers to the same.

2.3.2 Climate change effects and their impact on dairy production

Climate is the characteristic condition of the earth's lower surface atmosphere at a specific location. Weather, on the other hand, is the day-to-day fluctuations in these conditions at the same location (FAO, 2008). Over time, humanity has depended on the natural environment; and on weather and climate in particular, for survival. This makes the atmosphere a valuable resource base that requires sound management (LVOS, 2013).

Although FAO (2008) notes that there is no internationally agreed definition of the term *climate change,* causes of climate change are somehow complex, including extra-terrestrial factors, terrestrial factors, solar variations, ozone depletion, and increase in greenhouse gases due to anthropogenic factors, etc. (LVOS, 2013; Sivaramanan, 2015). Even though greenhouse gases (Carbon dioxide, Methane, Nitrous Oxide, Chloro-fluoro-carbons and Halogens) occur naturally and are essential to the survival of humans and other living organisms, studies have shown that the current cause of climate change is largely as a result of high concentration of greenhouse gases into the atmosphere since 1750 due to anthropogenic interference (LVOS, 2013; Sivaramanan, 2015; UNEP, 2019). Farmers, however, cannot at a glance see the connection between human activity and climate change, thereby compromising efforts to mitigate climate change. Adaptation, therefore, remains the most feasible option to support smallholder dairy farmers in their efforts to sustain production and income earning.

There is overwhelming research evidence indicating that the climate is rapidly changing globally (Stern, 2006; Anup, 2015), and efforts to reduce the sources or enhance the sinks of greenhouse gases will take time (Elum *et al*., 2017; Harvey *et al*., 2018; GEF, 2020).Studies have shown that with climate change, Africa (the World's poorest Continent) is facing the greatest catastrophe in human history, largely owing to its low adaptive capacity that is heavily compromised by high poverty levels and over-dependence on rain-fed agriculture (Chepkoech *et al*., 2018; UNEP, 2019: NASA, 2020). Thus, there is a need for governments and stakeholders to support farmers in their efforts to adapt to climate change.

Average global surface temperature, for example, rose by between $0.5^{o}C$ and $0.6^{o}C$ in the 20^{th} Century; with Climate experts predicting it to rise by between $1^{o}C$ and $6^{o}C$ by the end of 21^{st} Century(Sivaramanan, 2015; UNEP, 2019). Africa was found to be averagely $0.5^{o}C$ warmer than it was 100 years before 1990; with the temperature rise expected to create changes in rainfall pattern, frequency, intensity, timing, rate of change, geographic distribution, and other characters of extreme climate events; such as floods, droughts, severe storms, heat/cold waves, etc.(LVOS, 2013).Arid and semi-arid parts of Northern, Western, Eastern, and Southern Africa are becoming drier, while equatorial and some parts of Southern Africa are becoming wetter (LVOS, 2013; NASA, 2020; AfDB, 2020). Whereas these studies have brought to the foe the climate change effects, the challenge is that they are at macro-scale. How changes in climate have affected local communities (micro-scale) is important to understand for programming sustainable, realistic and farmer-friendly local climate change adaptation programmes.

Scientific models indicate that temperatures are expected to continue to rise in Kenya in all seasons to about 1^{o}C by the 2020s and 4^{o}C by 2100. While warming will vary from region to region within Kenya, a much greater variability is expected with respect to precipitation patterns; to the extent that wetter conditions will most likely be observed during the short rainy seasons, while a general decrease in mean annual precipitation is expected within the country(Lisk, 2009). The effects are projected to include increased flooding and droughts, all of which are expected to increase in intensity over the century; yet there are great challenges of regional and international knowledge gap, and a severe lack of local weather data in Kenya in particular; and Africa as a whole (UNDP, 2012; UNEP, 2019).

The frequency, intensity and impact of the climate change effects is growing over time, manifesting in such cases as of drought, famine, and floods that cover more than one state and affect large populations(One Acre Fund, 2020). Such is the 2011 Horn of Africa famine that covered Somalia, Eastern and Southern Ethiopia and Northern Kenya (Huho *et al*., 2011; Mosley, 2012; Amamou *et al*., 2018). Yet, such documented climate change effects still cover regions and large parts of a country, and are non-specific.

Effects of climate change occur at all levels and are bound to disrupt the earth's ecological systems with serious negative consequences on agricultural production, forests, water supply, health systems, and overall human development (Chepkoech *et al*., 2018). Most countries are increasingly becoming prone to droughts and floods, with rural farming practices, deforestation and charcoal production having a dramatic impact on severity of floods (UNISDR, 2012; Chepkoech *et al*., 2018; One Acre Fund, 2020). While climate change effects have far-reaching regional ramifications, differences in political environments and economic profiles would greatly undermine the possibility of mounting a regional response (Mosley, 2012; Sivaramanan, 2015), meaning that the most feasible climate change intervention would be at national or local (community) level.

Some of the effects of climate change that have been witnessed in Kenya include changes in precipitation pattern, and on food production through a shift in the agro-climatic zones suited to the growth of specific crops; changes in crop yields, livestock output, and fisheries production (Chepkoech *et al*., 2018). The result is that some farmers have been forced to shift from modern vegetable farming to traditional crops which are more resistant; Mombasa is affected by droughts, strong winds, and sea rise; and in January 2010 floods hit North Rift Valley, a case which had never been witnessed hitherto; and the death toll from floods in Budalangi, Nyatike, Nyando, Kisumu, Turkana and parts of North Eastern Kenya has been on the rise (Huho *et al*., 2012; LVOS, 2013). For smallholder dairy farmers, rising temperatures would most likely lead to emergence of new strains of livestock parasites and diseases, loss of some species of livestock forages and a drop in the quality of the remaining species(One Acre Fund, 2020). There could also be a drying of water bodies, and declining water quality(Lisk, 2009). Problems with livestock fertility and general health may also be witnessed, leading to a drop in milk production (WWEC, 2004; UNDP, 2012; Clay, Garnett & Lorimer, 2020). Whereas these effects have been documented, they are still general and not quantifiable, as they are based on climate modelling studies, and not on local empirical studies.

This study, therefore; undertook to interrogate the perceived effects of climate change on smallholder dairy farming in Migori County, categorizing the effects on water and pasture, milk production, animal health, fertility and breeding, marketing, and adaptability into three categories: Low effect, Moderate effect and High effect. This would enable the stakeholders to have a better understanding of the effects, and prioritize on the responses based on the perceived level of climate change effect.

2.4 Global adaptive strategies of the dairy industry to impacts of climate change

The most realistic approach to tackling the effects of climate change, particularly for developing nations and Africa with highest vulnerability, is enhancing adaptations to the effects(Elum *et al*., 2017; Bosire *et al*., 2019; AfDB, 2020). It is through adaptation that farmers are able to meet their food, income and livelihood security needs amidst changes in the climate and socio-economic conditions (Hassan & Nhemachena, 2008; Bebe, 2013; Bosire *et al*., 2019).Adaptation is the process by which strategies to moderate, cope with, and take advantage of the consequences of climate events are enhanced, developed, and implemented(Bebe, 2013; Elum *et al*., 2017; Climate Chance, 2019). People's adaptive capacity to climate change involves the management of risks posed by climate change and climate variability, and may be viewed as an inter-play of technology, resources, infrastructure, human capital, well developed institutions, and equity(NASA, 2020). Adaptation measures include the prevention, tolerance, or sharing of losses, changes in land use or activities, changes of location, or restoration (Climate Chance, 2019). These are, however, general and not specific to any group or farming community. It would be important, therefore; to understand how local smallholder dairy farming communities adapt to climate changes.

Mutua (2013) asserts that greater economic resources increase people's adaptive capacity, while lack of knowledge, skills, technology and financial resources limits their adaptation options. Accordingly, Climate Chance (2019), add that less technologically advanced regions are less likely to develop and/or implement technological adaptations. Similarly, lack of informed, skilled and trained personnel reduces people's adaptive capacity; whereas greater access to information increases the likelihood of timely and appropriate adaptation (Elum *et al*., 2017; Climate Chance, 2019). Further, Mutua (2013)further insinuates that greater variety of infrastructure can enhance people's adaptive capacity, as it provides more options; and that characteristics and location of infrastructure also affect people's adaptive capacity. Smit & Pilifosova, (2018) and Climate Chance (2019) noted that well-developed social institutions help people to reduce the impacts of climate-related risks, and, hence; increase their adaptive capacity. Similarly, Bebe (2013) and Smit & Pilifosova (2018) observed that equitable distribution of resources increases people's adaptive capacity; with both availability of, and access to, resources being important in determining people's adaptive capacity. It is only by studying and understanding local smallholder dairy farming communities' climate change adaptation and the factors determining it that governments and stakeholders would be advised on the gaps and best approaches to enhance local climate change adaption.

Adaptation actions vary, and may include coping; mal-adaptation; hard-and soft-adaptation; anticipatory- and reactive- adaptation; high regret, low regret and no regret options (Elum *et* *al*., 2017; Climate Chance, 2019). Bebe (2013) views adaptation as an ongoing, sustainable activity, which involves planning; adding that coping is where someone uses existing resources to respond to climate impacts in the short term and is an intermittent activity that potentially can degrade the resource base. Elum *et al*. (2017) and Climate Chance (2019) on their part take time to explain the difference between anticipatory and reactive adaptation. According to them, anticipatory adaptation, also referred to as ex-ante; is usually that which someone undertakes in preparation for extreme climate impacts. On the other hand, reactive adaptation, also known as ex-poste; is where one undertakes certain actions in response to some extreme climate impacts (Elum *et al*., 2017; Climate Chance, 2019). It would be important to first gather local adaptation data among farming communities before classifying them into soft, anticipatory, reactive, high regret, low regret or no regret; or anticipatory and reactive adaptation measures.

Adaptation to climate change in smallholder dairy production systems in Kenya cannot be ignored because of its importance, owing to the socio-economic value of the systems. Kenya lost 70% of the total livestock due to droughts in the worst drought ever to hit the country in 1991-1992 (Huho *et al*., 2011). Through adaptation, farmers are able to considerably reduce the potential damage as a result of climate change. Despite having low adaptive capacities to climate change effects, hence greater vulnerability, Bosire *et al*. (2019) have demonstrated that Sub-Saharan Africa farmers have somehow been able to adapt over the years to climate change effects. Yet, local adaptation levels would still vary from place to place, hence; the need to understand how smallholder dairy farmers of Migori County are adapted to climate change effects.

Adaptation in smallholder dairying is necessary to ensure reduction of livestock loss and improving livestock production systems. Whereas Kimenju (2009) noted that smallholder dairy farmers adapted by introducing fodder banks, improving water management, and controlling animal diseases and nutrition; Howden *et al*. (2007) and Bosire *et al*. (2019) cited improving the health of herd through proper nutrition, especially during the dry seasons and drought, diversification of enterprises (crop-livestock mix and/or rearing of diverse species of livestock in the same farm), and use of indigenous and more adaptable fodder trees and shrubs. Yet, adaptive measures vary as a function of farmers' own characteristics, technology-based characteristics, institutional factors, among others (Newsham *et al*., 2011).

Considering the fact that the study was conducted in a non-pastoral system, the study considered farming types adopted by farmers, breeds of dairy cattle kept, number of dairy cattle kept, rearing methods adopted, level of labour investment in the dairy enterprise, and sustaining an increasing trend in income from milk sales as the adaptive strategies. These were viewed as climate change adaptive technologies; which smallholder dairy farmers could be adopting. The last of these seem not to be a technology itself, but is actually the sum total of all the adaptive practices the farmer may have employed, and assures sustainability of the dairy operations in the advent of climate change.

2.5 Factors that influence producers' adaptation to climate change

Scientists agree that adaptation to climate change and risks takes place in a dynamic social, economic, technological, biophysical, and political context that varies over time, location and sector (Smit & Pilifosova, 2018), noting that socio-economic status is an important factor that affects respondents' behaviour and attitude towards climate change adaptation (Ihemezie*et al*., 2018). Whereas Smit & Pilifosova (2018) identified economic wealth, technology, information and skills, infrastructure, institutions, and equity as the main features that determine communities' adaptive capacity to climate change effects are; they were quick to add that the degree of vulnerability varies with region, time and sector. By this then, it is hard to predict the extent to which regional, temporal and sectoral variations would influence a community's vulnerability, and hence; climate change adaptation.

Whereas studies by Okuthe*et al*. (2007); Okuthe*et al*. (2013) and Amuge & Osewe (2017) tended to describe Kenyan smallholder dairy industry, considering the influence of various farmers' socio-demographic factors on agricultural technology adoption; this study looked at the influence of Gender; Age; Marital Status; Highest level of Formal Education; Household size; and Years of experience of smallholder dairy farmers of Migori County in the industry in relation to climate change adaptive strategies adopted by the farmers. Besides, the study considered farmers' perceptions, knowledge and institutional support to help in climate change adaptation.

The study also considered the Number of dairy cows kept (Less than 2 or 2 and above); Types of dairy cows kept (Pure breeds or cross-breeds); Rearing methods adopted (Intensive or Non-intensive); and Type of farming practiced (Pure dairy or mixed crop-and livestock farming). Others are, breeds of dairy cattle kept (Pure/crosses of Friesian or pure/crosses of Non-Friesian); Fodder source for dairy (Own fodder or Non-own fodder); Level of labour investment in the industry (Family labour or Non-family labour); trend in income from dairy enterprise (increasing or decreasing trend) as the possible adaptive strategies.

The next section of this Chapter attempts to review literature pertaining to the factors influencing smallholder dairy farmers' adaptive strategies to effects of climate change in the study area and the adaptive strategies themselves. It is worth noting that the determinants of climate change adaptive capacity of smallholder dairy farmers are neither independent of each other, nor mutually exclusive, with the adaptive capacity being a function of several determinants and varying widely between countries, regions, groups, and over time (Smit & Pilifosova, 2018).

2.5.1 Gender

Depending on how people in a particular community are socialized, and the various gender roles assigned to various sexes, there could be considerable differences in the smallholder farmers' perceptions of climate changes in the region over time based on being male or female(CARE, 2009).Generally, in Sub-Saharan Africa, women continue to suffer disproportionately from lack of access to education, health care and job opportunities, malnutrition, and weak economic and political participation (Midgley & Antzoylatos, 2012).

Several study findings suggest that gender-differentiation is related to climate change adaptation among communities (Smit & Pilifosova, 2018) and that female-headed households are poorer that male-headed ones, with women having low levels of reproductive choices compared to men, and often facing gender-based violence, hence; compromising their adaptive capacity (Midgley & Antzoylatos, 2012). Abayomi (2013) asserts that several constraints to accessing production resources would most likely be responsible for female-headed households being less productive than their male counterparts. Findings by Okuthe*et al*., (2007); Akhter & Olaf, (2016); and Zamasiya*et al*., (2017), clearly demonstrate the significant influence of gender on agricultural technology adoption and climate change adaptation.These studies imply that in terms of adaptation, women begin from a disadvantaged position in most communities in Africa compared to men, but the studies do not explicitly explain how governments and stakeholders have worked together in efforts to try to address such gender-differentiation in rural smallholder dairy farming communities.

Likewise, there could be considerable gender differences in the smallholder farmers' access to institutional support to help cope with climate change effects; and the skills to adapt to climate change effects based on being male or female (Abayomi, 2013; Tegegne, 2017). Findings of several studies tend to support this. Ntege – Nanyeenya *et al.*, (1997) found that roles and responsibilities of household heads as either male or female may affect technology adoption either positively or negatively. While the World Bank (2001) found that in many parts of the developing world men rear large stock,while women mainly rear small stock (sheep and goats); Budak*et al.*, (2005) considered the role of women in the labour distribution, decision-making, reasons for rearing small ruminants and the importance of extension service as an information source among 100 women in 10 villages in the Taurus Mountains, Turkey. The study by Budak*et al.*, (2005) showed that in 94.0% of the farms studied, the women and girls did milking; and made cheese and yoghurt. Women and girls contributed 52% and 19.0%, respectively of the total labour involved in cleaning the sheep and goat barns. The study also observed that women and girls tended to be more involved in labour than technical services, while men were more involved in and made decisions regarding activities that are technical and require money, such as vaccination. Findings by the World Bank (2001) is general; and even though findings by Budak*et al.*, (2005) are specific to Taurus Mountains in Turkey, they cannot be extrapolated to Africa, and Migori County; for that matter largely owing to cultural differences. It is therefore, necessary to conduct a local community based gender-based analysis to how climate change adaptation among smallholder dairy farmers would vary with gender differences.

At a more local level in Western Kenya, Valdivia (2001) found that among the Samia community, women tend to rear goats and poultry and prefer technologies that are extensive and relating to food crops, such as tethering goats and feeding them sweet potato vines; while the men would prefer capital-intensive technologies. Hassan & Nhemachena (2008) observed that female farmers are more likely to adopt natural resource management and conservation practices compared to their male counterparts, probably because nature tends to appeal more to females than males. Whereas findings by Hassan & Nhemachena (2008) would also explain why Samia women tend to prefer technologies that relate to crops (nature), it does not explain why Ndiema (2002) in her study of adoption of wheat technologies in Njoro and Rongai division of Nakuru District-Kenya, found that males made most of the decisions regarding technology adoption. The most probable explanation for this would be because technology adoption involves commitment of resources, the control of which is mainly in men’s hands in most parts of Kenya. Nevertheless, the finding by Ndiema (2002) that despite 72% of the study farmers being males, there were more female adopters (81%) than male adopters (71%) would still be explained by the hypothesis by Hassan & Nhemachena (2008) that nature (wheat farming in this case) tends to appeal more to females than males. This is against the expected male dominance over resource and decision – making, considering the income that accrues from wheat production. More in-depth studies on influence of gender on technology adoption would be needed to help unravel the mystery behind this.

While Okuro *et al*., (2002) found gender to significantly influence adoption of maize production technologies, similar to findings by Atibioke *et al*. (2012) regarding the adoption of grain storage technologies in Nigeria; Odhiambo (2014), on the other hand; found that the gender of the household head had no significant influence on the adoption of the crossbred goat technology and technology-related practices in Nyatike, Migori District-Kenya. Similar findings of gender having no significant influence on technology adoption were made by Amuge & Osewe regarding adoption of feed based dairy technologies among smallholder dairy farmers in Ekerenyo Division, Nyamira District-Kenya. Thus, whereas findings by Odhiambo (2014) and Amuge & Osewe (2017) agree with those by Hassan & Nhemachena (2008) that a lot of literature exists that shows that the gender of the farming household head has no significant influence on their decisions to adopt conservation measures; the findings differ with those by Okuro *et al*., (2002) and Atibioke *et al*. (2012). These findings show that there is mixed influence of gender on agricultural and livestock-based technologies technology adoption.The findings, however, do not tell much on adoption of climate change adaptation technologies, which could go either way depending on the culture, locality and support from government and stakeholders, among others. Thus, findings of this study would add to the volume of available literature, on the effect of gender on the adoption of climate change adaptive technologies in Kenya and Sub-Saharan Africa. This could be subject to further studies in similar contexts in the tropical world.

2.5.2 Age

The chronological age of a person may bring with it some level of physiological and emotional maturity to enable one better handle stressful situations (Zamasiya*et al*., 2017). Sometimes, with age comes the much-needed experience to handle a particular situation (Ndiema, 2002). Findings of several studies point to the same, with respect to technology adoption and climate change adaptation. For example, in Leeds, the United Kingdom, Ihemezie*et al*., (2018) undertook a study to establish the socio-economic factors influencing individual and household adaptation to climate change. Whereas the study established that 78.8% of the study respondents kept their houses warm by turning on the heater, most of the elderly people in the United Kingdom did not consider heat wave a serious climate risk that requiresadaptation. Rather, social networks was the main detrimental measure that could exacerbate vulnerability to climate change for the elderly.

Midgley & Antzoylatos (2012) while studying gender-and age-responsive adaptation to climate change in Southern Africa, noted that older people are particularly vulnerable to climate change effects. Smit & Pilifosova (2018), further assert that differentiation in such socio-demographic variables as age are seen as being related to climate change adaptation. Study by Abayomi (2013) exploring the factors explaining dairy cattle adoption behaviour among smallholder farmers in Western Kenya indicated that farmers in their middle ages of 40-50 years tended to adopt dairy cattle more than younger ones (of less than 40 years and older ones of over 50 years). Dehinenet *et al*., (2014) concluded that age of household head, among others; positively and significantly influenced both the adoption of dairy technology and level of adoption in selected zones of Amhara and Oromia National Regional States of Ethiopia, consistent with findings by Amuge & Osewe (2017) regarding the adoption of feed based dairy technologies among smallholder dairy farmers in Ekerenyo Sub-county, Nyamira District-Kenya. Ntege-Nanyeenya *et al*. (1997) found that the chronological age of a farmer could generate or erode his/ her confidence regarding certain technology practices and hence; greatly influence adoption in the sense that, with age the farmer becomes more or less prepared to take the risks associated with trying out a new technology. Irungu (1998) and Ndiema (2002) found age to be very much related to experience and skills in a particular technology, but where education and energy are required, younger farmers are more likely to adopt a technology. She concluded that the young farmers are energetic and enthusiastic to adopt the technologies. Assertions by Irungu (1998) and Ndiema (2002) that young farmers are energetic and enthusiastic to adopt new technologies are consistent with findings by Seger (2011) that age was a barrier to adoption of new technologies by the Extension personnel, but more importantly, by the clientele; with the older generations finding it difficult to adopt new technologies and vice-versa.Findings by Seger (2011) are further backed by those by Weinberg (2004) regarding the adoption of new computer technologies, whereby young workers were fund to be better adapted to new technologies. Moreover, Odhiambo (2014) found that young farmers dipped their goats in acaricide solutions more frequently compared to older ones.From these studies, it appears where new technology is involved, the youth tend to adopt them faster than the old farmers. On the other hand, when it comes to climate change, with age comes increased exposure and probably experience to deal with the effects, hence; old farmers tend to adapt better compared to younger ones. Nevertheless, this is still a general observation, as the age-influence would probably differ with the nature and type of climate change adaptation technology in question, a fact that this study pursued.

Hassan & Nhemachena (2008) noted that available literature point to the fact that there is mixed influence of age on the skills that farmers employ to adapt to climate change, and to adopt new technologies. In this respect, while some studies observed that there was no effect of age on the adoption of soil and water conservation activities, other studies found that age is significantly and negatively related to farmers' decisions to adopt new technologies; while a few found that age is significantly and positively related to farmers' decision to adopt conservation measures. In their study, Hassan & Nhemachena (2008) assumed that older farmers are more experienced, hence; would easily adapt to climate changes compared to younger ones. The latter, being better planners, would be able to shift to more mixed farming and irrigation systems compared to older ones, Nevertheless, the study found out that age of the farmer did not have significant influence on the adaptation of the farmers to climate change effects. This was against the expectation. Thus, from the reviewed literate there appears to be mixed influence of age on smallholder dairy farmers' climate change adaptation. This study, therefore, would add to the wealth of literature that show that age eitherhas an influence or no influence on smallholder dairy farmers' climate change adaptation. This would then be subject to replication or further examination in other parts of the tropical world, bearing in mind the context in which the study was conducted.

2.5.3 Marital Status

Depending on an individual's socialization, the marital status of a person may bring along with it some level of physical and emotional stability, with Abayomi (2013) insinuating that marriage may motivate desire for adoption of certain technologies, such as raising dairy cattle. It often even brings with it some level of financial stability, particularly if married couples openly share their resources, including family labour (Abayomi, 2013). While literature exists to support this (Akinbami*et al.*, 2012; Muthui, 2015; Akhter & Olaf, 2016), there is not much literature in this regard available to support this in the Kenyan context, a gap that this study endeavoured to fill by looking at the influence of the marital status of smallholder dairy farming household heads on their adaptive strategies to climate change effects in Migori County-Kenya. Findings would add to the volume of available literature that either support the fact that marriage influences climate change adaptation or disputes the same.

2.5.4 Level of Education

Often education is associated with knowledge in a particular field, with Abayomi (2013) noting that education motivates technology adoption. Thus, in most cases, it is assumed that the highly educated farmers are more exposed to modern sources of information, hence; are more knowledgeable (Tegegne, 2017). Smit & Pilifosova (2018) noted that educational level is related to the ability of a household and community to cope with climate-induced risks and asserted that successful climate change adaptation requires recognition of the necessity to adapt, knowledge about available options, the capacity to assess them, and the ability to implement the most suitable ones. They further added that building adaptive capacity requires a strong, unifying vision; scientific understanding of the problems; an openness to face challenges; pragmatism in developing solutions; community involvement; and commitment at the higher political level. Findings of several studies tend to support this (Abayomi, 2013; Akhter & Olaf, 2016; Amuge & Osewe, 2017).

Godoy *et al.*, (1998) observed that education played a more prominent role in influencing adoption of modern agricultural technologies among relatively autocratic indigenous villages in Bolivia, concluding that conventional determinants of new farm technologies may need reappraisal in more autocratic settings. Weinberg (2004) found that among the less educated workers, existing knowledge could be important for learning new technologies, especially if it is related to the one it is intended to replace. Ntege–Nanyeenya *et al*., (1997) while studying the factors that affect adoption of new technologies for maize production by farmers in Uganda, found that formally educated farmers were more likely to adopt the Longe 1 maize technology by a factor of 4.3 than their illiterate counterparts were. Akhter & Olaf (2016) found that the number of adaptive practices adopted by farmers are positively associated with education, among other socio-economic factors. Ndiema (2002) found that education level significantly influenced fertiliser – and improved seed – use in wheat production among wheat farmers in Njoro and Rongai divisions of Nakuru District, Kenya. Wanyoike *et al*., (2002) also found farmers' educational level to significantly influence adoption of Calliandra in all farms under their study, concluding that better educated farmers are more likely to learn about new technologies sooner than their lowly educated counterparts. This conforms to findings by Irungu *et al*. (1998) that education level significantly contributes both to the probability and level of adoption of maize production technologies; and by Atibioke *et al*. (2012) that education significantly influenced the adoption of grain storage technologies in Nigeria. All these studies, however, were conducted on crop-based and soil and water conservation-based technologies and not on technologies related to smallholder dairying. Moreover, the studies were all conducted on technology adoption and not on climate change adaptation, a gap that this study was handy to fill.

Hassan & Nhemachena (2008) found that there exist several literature that back finding that better education and more farming experience improve awareness of potential benefits and willingness to participate in local natural resource management and conservation activities. Thus, educated and experienced farmers are expected to have more knowledge and information about climate change and agronomic practices that they can use in response. In their study of over 8,000 farmers in sub-Saharan Africa, therefore, Hassan & Nhemachena (2008) expected that improved knowledge and farming experience would positively influence farmers' decisions to take up adaptation measures. Whereas the study by Hassan & Nhemachena (2008) was on climate change adaptation, it was at a macro-level in Sub-Saharan Africa, hence; findings may not be very applicable to local (micro) level. This study attempted to establish the influence of education level of the smallholder dairy farming household heads on their adaptive strategies to climate change effects in South-western Kenya. Findings would, thus; either add to the strong evidence relating education to climate change adaptation, or digress from it.

2.5.5 Household Size

Adoption studies indicate that a farmer's household size has a significant influence on his adoption of new agricultural technologies, largely as an important source of labour

(Muzamhindo*et al*., 2015; Akhter & Olaf, 2016; Amuge & Osewe, 2017). Farmers with larger household sizes tend to take up labour-intensive technologies more easily compared to those with smaller household sizes (Gbetibou, 2009; Dehinenet *et al*., 2014; Amuge & Osewe, 2017; Abadi,*et al*., 2018). In their study of over 8,000 farmers in several countries in the Sub-Saharan Africa, Hassan & Nhemachena (2008) noted that although it is possible to hire labour to support farming activities, most rural farmers are not able to do this. Dehinenet *et al*., 2014 noted that household size positively and significantly influenced both the probability and level of adoption of dairy technologies in Ethiopia. Similarly, Akhter & Olaf (2016) found the number of adaptive strategies being practiced by farmers in Pakistan to be positively associated with household size. This corroborates findings by Abayomi (2013) regarding adoption of dairy cattle in Western Kenya, with households with large family sizes tending to take up the technology. Even though findings of these studies point to the fact that in Sub-Saharan Africa, and in the tropical world, the larger the household size, the more likely is the household to take up new agricultural technologies that require labour; some of these studies (Abayomi, 2013; Dehinenet *et al*., 2014; Amuge & Osewe, 2017; Abadi, *et al*., 2018) were on dairy technology adoption and not on climate change adaptation. Some of the studies that were on climate change adaptation also tended to be at the macro-level (Hassan & Nhemachena, 2008), hence; not very applicable to local situations as findings of this study would.

This study sought to establish the influence of family size on smallholder dairy farmers' adaptation to climate change. Findings would add to the volume of literature supporting a positive relationship, or digress by evidencing a negative or no relationship between household size and climate change adaptation. This would be the basis for further studies elsewhere, especially in the tropical world.

2.5.6 Experience in dairying

With respect to climate change adaptation, studies (Midgley & Antzoylatos, 2012; Ihemenzie *et al*., 2018) show that previous experience or exposure to extreme weather conditions is a driver, just as social acceptability and long-term financial reward.While maturity and some experience in handling difficult situations generally come with age, the number of years one takes in a particular business gives him or her more focused experience relating to the particular business (Dehinenet *et al*., 2014; Tiyumtaba, 2016; Hitayezu & Ortmann, 2017).

Weinberg (2004) in his study of the adoption of new computer technologies found that young workers are better able to adapt to new technologies. He argued that while economists use vintage human capital models to conclude that young workers are the primary adopters and beneficiaries of new technologies, research has indicated that technological progress in general, and computers in particular, are biased toward skill. It was found that among college graduate men, young workers adopted computers most intensively, while at lower levels of education, more experienced workers are most likely to use computers. Hassan & Nhemachena (2008) found that the more experienced farmers are more likely to adapt to climate change than the less experienced ones; similar to findings by Gbetibou (2009) in South Africa. These findings are also consistent with findings by Amuge & Osewe (2017) that the more experienced smallholder dairy farmers are more likely to adopt feed based dairy technologies.Although from the studies experience seems to positively influence smallholder dairy farmers' climate change adaptation, the studies were largely conducted at the macro-level, hence; the findings may not necessarily be applicable to local situations as in Migori County.

2.5.7 Farmers' perceptions of climate changes

Several empirical studies have been conducted world over, and in Africa; on farmers' perceptions of the climate changes that have taken place over time and the measures that farmers have undertaken to adapt to the same (Gbetibou, 2009; Banerjee, 2015; Elum *et al*., 2017; Chepkoech *et al*., 2018). Hassan & Nhemachena (2008) reviewed several literatures that analysed farmers' perceptions of climate change and the adaptations they perceived appropriate to the same; and then looked at the perceptions of over 8,000 agricultural households of climate change across 11 African countries, and their perceived adaptive strategies to coping with the same. The agricultural household heads were asked about their perceptions of changes in temperature and precipitation over the years. The findings showed that most (50%) of the farmers indicated that long-term temperatures are generally getting warmer; while precipitation is declining. About 30% were of the opinion that major changes have occurred with respect to the timing of the rains, while about 17% were of the opinion that droughts were getting more frequent. To adapt to the changes, the surveyed farmers tended to diversify crop production, use different crop varieties, change planting and harvesting dates, undertake more irrigation farming, increasingly employ soil and water conservation measures, ameliorate temperature effect through shading and shelter, shorten the growing season; and diversify from farming to non-farming production systems. The findings of these studies generally point to the fact that climate change adaptation practices tend to vary with locality, type of enterprise and climate change perceptions that the farmers have. The study by Hassan & Nhemachena (2008), however, is largely at macro level, and may not be very applicable to local situation as in Migori County-Kenya.

Elum *et al*. (2017) reported that majority (over 90%) of their study respondents in Southern Africa region perceived that the temperature had changed (95%) and that rainfall had also changed (97%) over time. This was found to be consistent with research findings on climatic projections based on modelling studies that projected extreme weather events in the region (Song et al., 2004). As a result of these perceptions, the farmers adopted a series of adaptive strategies that they perceived to be appropriate, given their knowledge, financial base, and level of access to technology, among others (Elum *et al*., 2017). Other studies (Banerjee, 2015; Panda, 2016) have also indicated that farmers increasingly perceive that there are climatic changes taking place in their communities with respect to temperatures and rainfall patterns; and that comparing farmers' perceptions on rainfall patterns with actual rainfall data, farmers' perceptions tend to more closely align with the results from the nearest meteorological or weather station. Moreover, farmers tend to rely on traditional forecasting systems, as they have limited access to modern climate forecasting and customised information for agricultural practice (Panda, 2016). These findings tend to point on two factors influencing farmers' climate change perceptions-first, that farmers' perceptions need to be compared to nearest meteorological stations for verification before taking a decision, and-secondly, that farmers rely heavily on traditional forecasting systems due to limitations in access to modern climate forecasting and customised information for agricultural practice. While the studies were at micro level, it would be good to undertake a similar study in Migori County-Kenya for comparison of findings. This would give the results a basis for wider applicability among tropical smallholder dairy farming communities.

The study by Hassan & Nhemachena (2008) categorized the agricultural households' adaptations to climate change effects into three major categories: diversifying into multiple crops and mixed crop-livestock systems, and switching from crops to livestock and from dry land to irrigation farming. Whereas farmers' perceptions of climate changes in Limpopo Basin in South Africa were found to be consistent with the climate data records for the same region, Gbetibou (2009) ironically found that only about 50% of the study respondents had adjusted their farming practices to adapt to climate change. These findings indicate that although farmers may perceive changes in local climate to be taking place, it may not necessarily translate to them adapting to the same. The implication is that climate change adaptation is a complex process that would be influenced by several other factors. This theory needs to be interrogated further, hence; the need for the study among smallholder dairy farmers in Migori County-Kenya.

Moreover, several perception studies of smallholder farming communities and climate change adaptation have been conducted globally, across Africa and Kenya (Wamugi, 2016; Merton, 2017; Tripathi & Mishra, 2017); there is minimal work done within Kenya's South-western region. Much of the climate change perception studies in Kenya have been done in the Central and Eastern parts of the country, hence; the need to undertake a study on climate change perceptions among smallholder dairy farmers in Migori County in South-western Kenya. Findings would add to the available literature supporting influence of farmers' climate change perceptions on their adaptation to the same.

2.5.8 Farmers' knowledge of climate change effects on dairying

The level of one's highest formal education plays a critical role in determining the level of one's knowledge and understanding of concepts and issues, with factors like the interest one has on the industry, types of friends one keeps, number of dairy cows a farmer keeps, and the production or rearing method adopted coming into play (Rogers, 1995; Odhiambo, 2014). Findings of several adoption studies (Ogalleh *at al*., 2012; Bagamba *et al*., 2012; Ochieng, 2015; Babatolu & Akinnubi, 2016) reveal that the more knowledgeable and more educated farmers are better placed to adopt technologies and practices compared to their less educated and less knowledgeable counterparts. Finding by Odhiambo (2014) found that the more educated and more knowledgeable smallholder goat farmers adopted the practices of control of inbreeding and supplementary feeding; housed their goats properly, and gave proper attention to kidding does compared to their less educated counterparts is consistent with that by Amuge & Osewe (2017) adoption of feed formulation technologies (on-farm feed formulation and total mixed ration) was low because they are knowledge-intensive technologies that necessitate farmers to learn and practice over a considerable period of time. Thus, adoption of such technologies would require both knowledge and experience. These findings tend to point to correlations between knowledge and experience. While in nature there is a lot of correlations among factors influencing technology- and climate change-adoption, such findings tend to dilute the influence of knowledge alone on climate change adaptation; a fact that this study sought to rectify by having a knowledge-based tool to establish the influence of knowledge on smallholder dairy farmers' climate change adaptation in Migori County.

Knowledge on smallholder dairy farming, climate change and adapting smallholder dairy farming to meet the challenges coming as a result of climate change effects, could be acquired by the farmers through training (Quddus, 2012; Dehinenet *et al*., 2014; Kuteesa & Waholi, 2019). This training could be provided by government livestock extension officers, private extension officers, research institutions, and/or universities, both public and private (Dehinenet *et al*., 2014; Feyissa*et al*., 2018; Seble *et al*., 2020).Feyissa*et al*., 2018(2018) noted that training increases the level of awareness of pastoralists and broadens their knowledge regarding advantages, management practices and other attributes of a technology; consistent with findings by Dehinenet *et al*., (2014)and Amuge & Osewe (2017) that participation of smallholder dairy farmers in training sessions significantly and positively influenced their adoption of dairy technologies. Smit & Pilifosova (2018) noted that climate change adaptive capacity of a community is likely to vary depending on the availability and access to technology, adding that successful adaptation requires a recognition of the necessity to adapt, knowledge about the available options, the capacity to assess them, and the ability to implement the most suitable ones. Again, these findings tend to cloud the influence of knowledge on climate change adaptation with that of access to climate change information, and support provided to the farmers. Whereas the interrelationship exists, it is worth isolating the influence of knowledge on climate change adaptation separate from these other factors. This is what this study sought to do, by having a knowledge-based tool.

Several studies in developing countries (Feyissa*et al*., 2018; Kuteesa & Waholi, 2019; Seble *et al*., 2020) indicate that training on dairy farming had a positive and highly significant relationship with the adoption of improved dairy husbandry practices, since training programmes influence the uptake of new technologies, help in achieving sustainable production, hence; increasing income and employment in rural areas. Kuteesa & Waholi (2019) noted that knowledge on improved technologies through training, availability of reliable and continuous technical support, increased and timely provision of medicine, increasing A.I facilities and strengthening extension services increased use of improved technologies among dairy households. This is consistent with findings by Quddus (2012) and Dehinenet *et al.*, (2014). Panda (2016) noted that lack of information on climate change adaptation and early warning system, lack of government intervention, lack of knowledge on drought resistant crops and varieties and lack of renovation of water bodies and irrigation systems were the main barriers to climate change adaptation at the community level in India. The studies by Feyissa*et al*., 2018; Kuteesa & Waholi, 2019; Seble *et al*., 2020 were essentially adoption studies based on livestock technologies. They are not climate change adaptation studies bringing out the influence of knowledge on smallholder dairy farers' climate change adaptation. Whereas studies by Panda (2016) was a climate change adaptation study, it was conducted on crop-based technologies, and not smallholder dairying as was the case with this study conducted in Migori County-Kenya.

2.6 The role of institutions and extension services in climate change adaptation in dairy systems

2.6.1 Institutions and organizational mechanisms for coping with climate change effects

Sustainable dairy development requires a good infrastructure and effective support services and institutions (Bebe, 2003; Abayomi, 2013). In this regard, government extension service, parastatal organizations providing farmer support services (such as Kenya Farmers Association [KFA], Agricultural Finance Corporation [AFC], commercial banks, etc.), research organizations (such as KALRO, ILRI, ICIPE, etc.), universities (both public and private), Non-Governmental Organizations (NGOs), Community-Based Organizations (CBOs), farmer groups (e.g. Dairy farmers' cooperative societies, and other farmer groups) and private companies (e.g. feed distributers, agro-chemical companies, agro-vets, etc.) all play a pivotal role in making farmers gain access to information and technology to help cope with climate change (Kasulo *et al.,* 2012; Okuthe, 2014; Wamalwa, 2015; Smit & Pilifosova, 2018). Due to technological advancement, the internet, radio, television, newspapers, brochures, pamphlets, and social media platforms (e.g. WhatsApp, Twitter, Instagram, Facebook, Linkedln, YouTube and Pinterest)also plays a critical role in disseminating information and technology regarding climate change adaption in smallholder dairying. It would, thus; be expected in the 21st century, that the national and county governments urgently consider tackling the effect of global warming on the performance of the dairy industry. Even though the Kenyan Government is making some good progress in enacting climate change adaptation policies, strategies and plans that will go a long way in supporting farmers in their efforts to adapt (Wilkes *et al*., 2020); the efforts have not borne fruits in Migori County. This is because, despite a great potential and favourable weather for dairy development, Migori County has remained milk deficient for quite a long time (GoK, 2019b). This is against the generality that Kenya is self-sufficient in milk and milk products (Odero-Waitituh, 2017), hence; need to interrogate how climate change adaptation could probably be accountable for this in Migori County.

Extension serviceby far still remains an important source of information on agronomic practices as well as on climate (Midgley & Antzoylatos, 2012; Amuge & Osewe, 2017; Smit & Pilofosova, 2018). While several adoption studies (Hassan & Nhemachena, 2008; Altalb*et al.*, 2015; Aremu *et al*., 2015) have shown that farmers with better access to extension services are more likely to adopt most agricultural technologies,a study by Takahashi *et al*., 2019 shows that extension was not a significant factor affecting the adoption of agricultural technologies. Instead, Takahashi *et al*., 2019 demonstrated that farmer-to-farmer approacheshad statistically significant influence on the adoption of agricultural technologies.In terms of climate change adaptation, this means that what is critical is not extension service par see, but, climate change information sources. This study considered the various climate source information sources available to smallholder dairy farmers of Migori County-Kenya and the organizations, institutions and groups that supported farmers to adapt to climate change.

2.6.2 Role of agricultural extension in improving climate change adaptation in dairy systems

Agricultural technology adoption process as described by Rogers (2003) and expounded by Dube & Gumbo (2017) is a mental decision-making process starting from when a smallholder dairy farmer gets to hear about the new approaches to sustainable smallholder dairy management that are also environment friendly, to the time of final adoption. Effective communication plays a great role in this, providing the stimuli to enable the smallholder dairy farmer to make informed decisions regarding the new technology(Altalb*et al*., 2015; De Janvry *et al*., 2016). The full cycle of the adoption stages as given by Rogers are: awareness, interest, evaluation, trial and finally adoption (Rogers, 2003). Key characteristics of innovations that would influence smallholder dairy farmers' adoption include: relative advantage compared to other innovations, compatibility with other existing values and past experience; complexity in its usage, trialability in terms of experimentation on a limited basis (i.e. On-farm trial) and the degree of observability of the results of an innovation (Osewe, 2009; Odhiambo, 2014; Altalb*et al*., 2015). Several factors would influence how the farmers process information at each of these technology-adoption stages. While some of the factors are clear, others are not very clear, necessitating studies of this nature to unravel.

Extension forms the link between the researchers and the farmers; transferring research findings in a manner and through appropriate media (i.e. effective communication) that would make the farmers make informed decisions and choices regarding the application of a new technology (research finding). The ultimate goal is to make the farmers, their households and the general community improve their living standards through their own initiatives, by careful and sustainable exploitation of the natural resource bases available to them within the ecosystems where they live(Altalb*et al*., 2015; Aremu *et al*., 2015). This way, the nation experiences economic growth and development (Bradfield, 1971; Aremu *et al*., 2015). Amuge & Osewe (2017) observed that farmers cannot successfully adopt a new technology unless they are made aware of it and have acquired the skills to incorporate it into their farming systems. Agricultural extension exists to provide farmers with a wealth of knowledge that is hoped to make them able to make informed choices that would in-turn enable them to change their attitude and behaviour for the better (Altalb *et al*., 2015; Dube & Gumbo, 2017). It is through this change in attitude and behaviour that a change in practice, and hence; development is experienced (Smit & Pilifosova, 2018). This would explain why Obayelu *et al*. (2017) found that access to information would have a great influence on the adoption of agricultural technologies by smallholder farmers. This implies extension services, as well as other information sources, would be critical in climate change adaptation among smallholder farming communities; a fact that this study sought to establish.

Roling (1988) explains extension objectives in relation to the problem solving cycle. Thus, extension assists farmers to become aware of the symptoms, to formulate the problem, identify the causes, generate alternative solutions and choose and implement an appropriate one, thereby accelerating learning for adoption(De Janvry *et al*., 2016).

The ultimate goal would be to have farmers change their practices that would therefore, see Kenya make a significant contribution to reducing global warming through sound livestock management practices. The secondary effect, and probably the most important for the smallholder dairy farmers, is that the adoption of the practices would help to improve household incomes, hence; contributing to the national economic growth and development (Aremu *et al*., 2015; Smit & Pilifosova, 2018). This, if research findings are not made available to farmers through extension or other means, then the goal of extension or any other climate change information source would be futile. For this matter, findings of this study will be discussed with extension experts from the Ministry of Agriculture, Livestock and Fisheries Development, and researchers from KALRO and ILRI before being refined. Once refined, key messages would be carefully selected from the findings and packaged in appropriate manner (e.g. banners, fliers, extension brochures and radio and television programmes) and then passed on to the farmers.

Despite the critical role played by extension, the lack of proper incentives for agricultural extension agents is greatly bedevilling the service and greatly hindering adoption of new technologies, including climate change adaptation practices (Takahashi *et al*., 2019). This gap is what is being filled by non-state actors, the electronic-, mass-, print-, and social-media (Aremu *et al*., 2015) in making farmers gain timely and emerging scientific technologies from research institutions (Altalb *et al*., (2015). This study evaluated the role played by agricultural extension in climate change adaptation by ranking the climate change information sources to see where the study respondents would place government extension. This would help to affirm farmers' view of the role extension plays in climate change adaptation or give indications of alternative emerging trends that could be strengthened to help smallholder dairy farmers better adapt to climate change.

2.7 Summary of Literature reviewed and identified gaps

The study reviewed literature pertaining to dairy production in Kenya (Abayomi, 2013; Odero-Waititu, 2017; Kibogy, 2019) and the study area (Simotwo *et al*., 2018), and considered the role played by both large scale dairying (Technoserve, 2008; Der Lee *et al*., 2016; Kibogy, 2019) and smallholder dairying (Muriuki, 2003; Wilkes, et al., 2020; FAO, 2020)to the local and national economies. The study also looked at the challenges facing smallholder dairying (Moran, 2005; TechnoServe, 2008; Abayomi, 2013), including climate change (Sivaramanan, 2015; Elum *et al*., 2017; Chepkoech et al., 2018) as well as opportunities (Muriuki, 2003; Odero-Waitituh, 2017; Kibogi, 2019).

The study reviewed the adaptive strategies of smallholder dairy farmers to climate change impacts (Elum *et al*., 2017; Bosire *et al*., 2019; AfDB, 2020), and the factors that influence smallholder dairy farmers' adaptation to climate change (Amuge & Osewe, 2017; Zamasiya*et al*., 2017; Ihemezie *et al*., 2018; Smit & Pilifosova, 2018; Kipkoech *et al*., 2018; Seble *et al.*, 2020). The review ended by looking at the role of institutions and extension services in climate change adaptation in dairying (Rogers, 2003; Wamalwa, 2015; De Janvry *et al*., 2016; Takahashi *et al*., 2019; Wilkes, 2020).

Whereas climate change adaptation has received increasing global attention, most of the studies that have been conducted have tended to be based on modelling techniques (Song *et al*., 2004; Awange *et al*., 2013: Climate Chance, 2019). Others that have tended to describe the impact of climate change on dairying, have tended to look at the macro-situation (Hassan & Nhemachena, 2008;), while those that have looked at the micro-level situation (Fadina & Barjolle, 2018; Ihemezie *et al*., 2018) have indicated that there is still fairly limited information and knowledge on the impacts of climate change on livestock production systems (Rojas-Downing *et al*., 2017; Amamou *et al*., 2018) and institutions addressing climate change-related issues owing to lack of and problems associated with climate data (Bagamba et al., 2012).

Micro-level data is still inadequate and there are problems with climate projections, and projected impacts and level of vulnerability of climate change on smallholder dairying systems for stakeholders to use in designing appropriate climate change mitigation and adaptation policies, strategies and plans to support local smallholder dairying communities (Climate Chance, 2019; AfDB, 2020; FAO, 2020). From the literature reviewed, most studies have focused on farmers that substitute for farming in times of disaster(Bagamba *et al*., 2012; GEF, 2020; FAO, 2020). There is therefore, need for more evidence of local communities adapting their smallholder dairying activities and techniques to cope with climate change and environmental challenges(Bagamba *et al*., 2012; Bosire et al., 2019; CGIAR, 2020).

Most climate change adaptation studies among smallholder dairy farming communities (Amuge & Osewe, 2017; Fadina & Barjolle, 2018; Jairo & Korir, 2019)have considered socio-economic factors of the respondents, relating them to climate change adaptation. This study has not only considered socio-demographic characteristics of the respondents, but also their perceptions, knowledge, and sources of climate change information; relating all these to their adaptation to climate change effects. Moreover, this is both an adoption and an adaptation study, hence its conceptualization was informed by more than one theory.

Whereas most climate change adaptation studies have qualitatively considered the influence of respondents' perceptions to climate change adaptation (Banerjee, 2015); this study has done so, both quantitatively and qualitatively, comparing the qualitative information with the actual climate change data from local meteorological station to ascertain its closeness to the reality. Moreover, whereas most studies (Tedesse & Dereje, 2018; Simotwo *et al*., 2018)have viewed respondents' climate change perception as their knowledge of climate change taking place in their study area, this study has considered the respondents' highest level of education and climate change perception separately. Secondly, the study has tested the respondents' knowledge of basic climate change and adaptation concepts separately, thereby being able to corroborate findings of respondents' level of knowledge on climate change with that of their educational status and perceptions regarding climate change and climate change adaptation.

Another unique feature of this study is that it is among the few (Newsham et al, 2011; Mashiza, 2019;) that has brought to the foe the smallholder farmers' great wealth of indigenous knowledge regarding climate predictions and providing timely and appropriate advisory services to enable famers better adapt to the predicted changes. This makes it a tool for governments, stakeholders, and policy makers to consider incorporating the great wealth of indigenous technical knowledge on climate change and climate change adaptation in formulating contextualized and appropriate climate change adaptation plans, strategies and policies.

Interestingly, whereas most studies have considered access to climate information as a way of gaining knowledge on climate change and climate change adaption, this study considered sources of climate change information as providing vital information on climate change that would re-inforce the study respondents' basic knowledge (based on their highest educational level) and climate change perceptions to enable the smallholder dairy farmers adapt better to climate change effects.

This study is further unique in that, whereas most climate change adaptation studies have used quantitative methods of data collection and analysis, this is one of the few *nested* studies (Marie *et al*, 2020); employing mixed methods of data gathering, with equal weight being given to both quantitative and qualitative approaches of data gathering and analysis. This enhances the credibility of its findings, making it endear itself to wider replication and adoptability of its findings by various stakeholders.

Finally, to the best of my knowledge, this is one of the first studies, other than that of Simotwo *et al*. (2018) to be carried out in South-western Kenya on climate change adaptation by smallholder farming communities. Regarding climate change and adaptation by smallholder dairy farming communities inSouth-western Kenya, it is the first, to the best of my knowledge. South-western Kenya is unique in that, it represents the dairy farming communities in marginal parts of Kenya, and it is deficient in milk and milk products, while Kenya is generally considered sufficient in these.

2.8 The Theoretical Framework

The Theoretical Framework for this study was based on the Action Theory of Adaptation to Climate Change advanced by Eisenack & Stecker (2010), who frame adaption as an individual or collective action, and build on established analyses of social action. The basic components of this theory are (collective) actors, means and ends of adaptation; where ends may be targeted at socio-economic or bio-physical units that are exposed to climate change, but also at the receptors (see Figure 1).

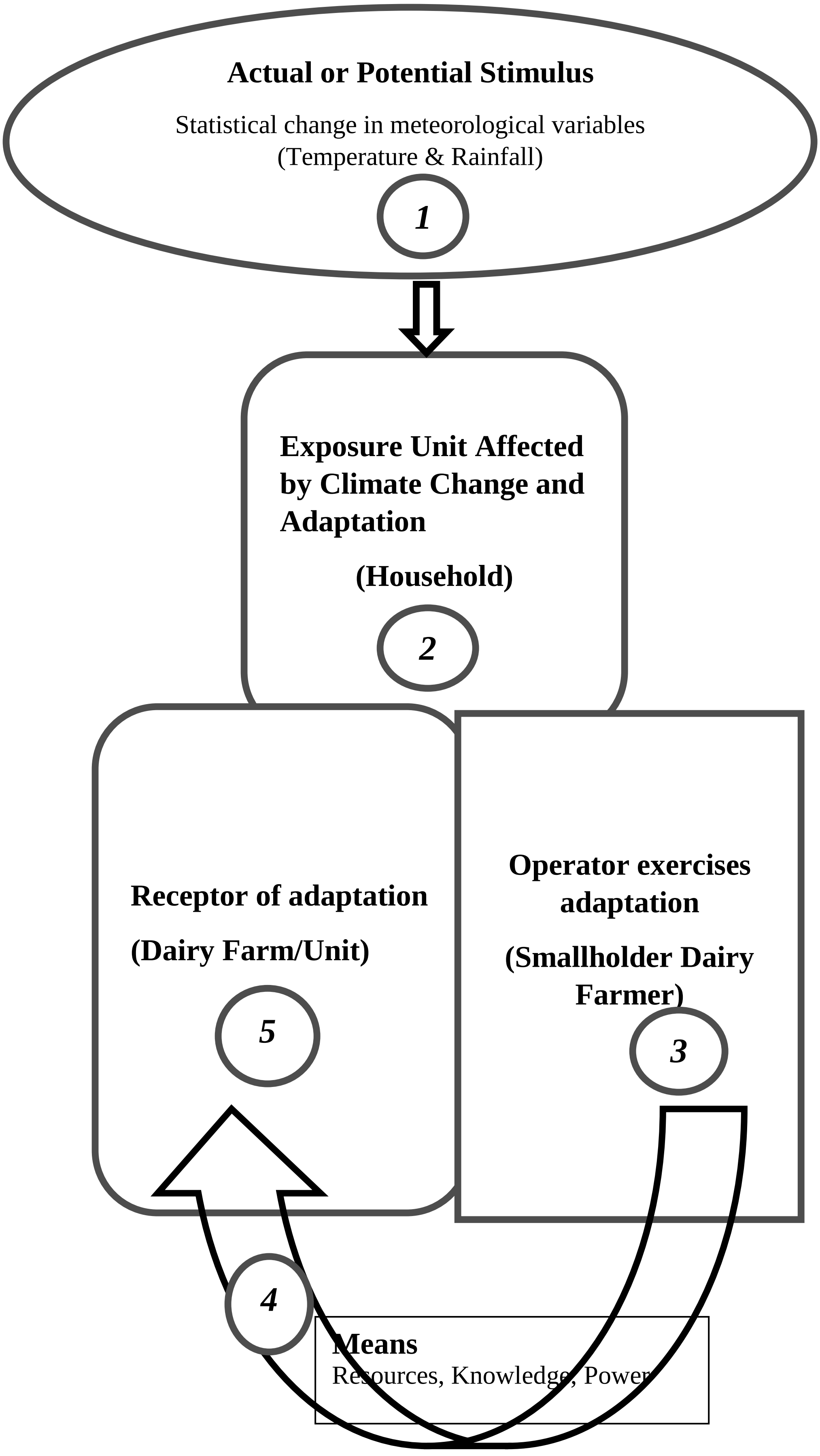

Figure 1: Action Theory of Adaptation to Climate Change
(Source: Adapted from Eisenack & Stecker, 2010)

Key:

- **1** Changes in temperature and precipitation as recorded by meteorological station in the study area
- **2** Household
- **3** Smallholder dairy farmer
- **4** Smallholder dairy farmer's perception and knowledge of climate change and climate change effects; climate change information sources, and institutional support for adaptation to climate change effects
- **5** Smallholder dairy unit/farm

In the schematic representation of the key concepts of the action theory of adaptation to climate change, boxes with rounded corners (box 2 and box 5) can be either actors or biophysical units, hence; box 2 in this study represents the household (actor), while box 5 represents the dairy farm (biophysical unit). On the other hand, operators are always actors (represented by a box with sharp corners); in this case being the smallholder dairy farmer (box 3). Operator, receptor and exposure unit (in this case, the smallholder dairy farmer (3), the dairy farm (5), and household (2)) are not necessarily identical, hence; are indicated by overlapping boxes.

Therefore, according to this theory, climate change affects many actors in different ways, and their reactions are strongly interlinked; with actions tending to come in means-ends-chains. As such, in order to understand climate change adaptation, stakeholders should aim at addressing these linkages. This study endeavoured to appreciate the climatic changes taking place in the study area, with respect to temperature and precipitation (1); with a view to assessing whether the smallholder dairy farmers (3) perceive that the changes have actually taken place (4), have an effect on the performance of the dairy farm (5) and are making efforts to adapt to the effects to improve and sustain dairy productivity (4). The study also endeavoured to establish the level of knowledge (4) that the smallholder dairy farmers (3) have of climate changes and their effects on dairying within the study site, and how this knowledge enables them to adapt to the changes for improved productivity and sustainability of dairy production in the farms (5). Finally, the study sought to establish the sources pf climate change information (4) accessible to smallholder dairy farmers (3) in the study site, as well as the institutions that support (4) the farmers to adapt to climate change effects in the study area (5).

The Action Theory of Adaptation to Climate Change stresses that important barriers are caused by a) a mismatch of the means that are necessary for adaption, that are available, and are actually employed; and b) externalities and high transaction costs due to the interlinked actors, receptors and units that are exposed to climate change. It is envisaged that the study has exposed the factors with the greatest influence in terms of determining how the smallholder dairy farmers in the study area, and in similar backgrounds within the tropics, would respond (i.e. adapt) in order to minimize climate change effects, remain in and sustain production, hence; contribution to the local and national economy.

Moreover, this study was further anchored on three other theories, namely; The Social Learning Theory advanced by Bandura, as cited by Singer (2016); Diffusion of Innovations Theory as advanced by Rogers (2003) and cited by Zilberman*et al*. (2012); and the Adaptation Theory by Zilberman *et al*. (2012). The Social Learning Theory postulates that individuals learn from each other's behaviour by observations; through a process known as social modelling. Thus, by observing peers, smallholder dairy farmers would enact similar (not identical) behaviour, such that they adapt an observed behaviour or practice to suit their own farming conditions. This could occur through inter-personal networks or through public displays, like in mass media (newspapers and pamphlets, radio or television). Social learning occurs through four steps, namely; **attention; retention; reproduction**; and **motivation**. Attention in this case refers to the ability of the smallholder dairy farmers to observe a behaviour or practice from other smallholder dairy farmers. Retention is the ability of the smallholder dairy farmers to remember a behaviour or practice; reproduction is the ability of the smallholder farers to perform a behaviour or practice, and finally, motivation refers to the driving force to change to the desired behaviour or practice. The motivation could come if the original observed behaviour or practice leads to an observable reward for the original performer (smallholder dairy farmer).

Closely related to the Social Learning Theory (Singer, 2016) is Roger's Diffusion of Innovations Theory (Rogers, 2003) that describes how individuals adopt or reject an innovation. The theory comprises five steps, namely; **knowledge, persuasion, decision, implementation,** and **confirmation.** The steps do not necessarily have to follow each other consecutively. Taking climate change adaptive strategy as an innovation, the theory stipulates that smallholder dairy farmers (i.e. potential adopters of climate change adaptive strategies)pass through the five stages over time in the diffusion process before finally adopting a new technology (climate change adaptive strategy). They first get to learn about the technology (usually from mass media or interpersonal channels, e.g. fellow farmers). Then, they get to be persuaded on the value of the new technology (either by extension agents, other farmers or institutions that have had closer contact with the technology). Next, they get to make an informed decision to adopt the new technology, before implementing it. Finally, the decision is reaffirmed or rejected (Singer, 2016; La Morte, 2019).Rogers identified two distinct classes of channels of communicating then new idea (technology or innovation). These are mass media and interpersonal channels. The mass media broadcast messages, such as news, educational information, or entertainment; from a sender to many receivers. On the other hand, interpersonal channels exist between individuals and allow for exchange between them that go back and forth. Thus, while the mass media initially plays a vital role in spreading awareness about an innovation, interpersonal networks become more important over time as people turn to other peers for opinions on and evaluation of new ideas (Zilberman *et al*., 2012; La Morte, 2019). In the Diffusion of Innovations Theory, time is an important aspect, as diffusion is a process that unfolds over time, and time is useful in categorizing adopters into different categories (i.e. innovators, early adopters, early majority, late majority and laggards) and determining adoption rate (Zilberman *et al*., 2012).

Singer (2016) underscores the fact that in the passive or active consumption of awareness knowledge and how-to knowledge, social system plays a critical role. Thus, the social structure and networks influences diffusion through values, norms, roles, and hierarchies; while the communication structure determines how messages may flow through the social system (Zilberman *et al*., 2012). Therefore, by gradually improving their understanding of climate change adaptive strategies through the opinion of peers and personal ties, the potential adopters (smallholder dairy farmers) would reduce the uncertainties associated with the new technologies (Singer, 2016).By this theory, therefore, adoption of climate change adaptive strategies would depend on the smallholder dairy farmers' personal characteristics, as well as the technology characteristics. The critical smallholder dairy farmers' characteristics of interest to the adoption of climate change adaptive strategies would be their socio-demographic characteristics. In this study, **gender, age, marital status, educational level, household size,** and **experience in dairying** were considered. Critical technology characteristics that would determine how fast the smallholder dairy farmers would adopt the climate adaptive strategies include climate change adaptive practice's **relative advantage, compatibility, complexity, trialability,** and **observability** (Rogers, 2003; Osewe, 2009; Singer, 2016).

Finally, the study was hinged on Adaptation Theory (Zilberman *et al.*, 2012), which emphasizes that, being responses to non-continuous changes, climate change adaptation involves understanding of discrete choices. To be considered successful, therefore, an adaptation must reduce the risk associated with climate change, or vulnerability to climate change impacts, to a pre-determined level, without compromising economic, social, and environmental sustainability. Considering adaptation at the micro (i.e., farm or household) level, therefore, smallholder dairy farmers will require to make a selection among discrete strategies, which this study sought to investigate. By this theory, and borrowing from Rogers (2003), five distinct stages of adaptation are recognized, just as with adoption(Zilberman *et al.*, 2012). The first is **awareness** (i.e. realization that global warming and greenhouse gas [GHG] emission occur and linking the two), **interest** (i.e. the realization that climate change may be harmful and should be addressed), **evaluation** (i.e. the climate policy debate conducted at multiple levels), **trial** (i.e. experimentation with various initiatives), and finally **adoption** (i.e. new institutions, adoption of sustainable climate-smart livestock rearing practices).

In this study, therefore, efforts were made to establish the perceptions of smallholder dairy farmers regarding climatic changes (with respect to temperatures and precipitation) taking place in the study area; their perceived effect of the changes on smallholder dairying; and how they are adapting to the same. Efforts were also made to appreciate the knowledge smallholder dairy farmers have of climate change and climate change effects; the relationship between this knowledge, their socio-demographic profiles, perceptions of climate changes, and climate change information sources to the adaptive strategies that they adopt.

2.9 The Conceptual Framework

The conceptual framework developed for this study was adapted from Population Survey Analysis developed by Educational Foundations and Research, University of North Dakota (Population Survey Analysis, 2014), with modifications as per discussions by Mugenda & Mugenda (2003) on the interactions by the moderator variables on the relationships between independent and dependent variables. Mugenda & Mugenda (2003) recognize independent variables as those variables that the researcher intends to manipulate in order to determine their effects or influence on the dependent variable, wherefore, the Independent Variables are also known as the Predictor Variables. On the other hand, a Dependent Variable, also known as a Criterion Variables attempts to indicate the total influence of arising due to the effects of the Independent Variable. Thus, A Dependent Variable changes as a function of the dependent variable. Nevertheless, a Moderator Variable is one that the researcher suspects is likely to influence the research results, but for which the study did not provide a control. Such variables, sometimes known as Extraneous Variables, would have an interaction effect between the Independent Variables and the Dependent Variables.

In this study, therefore, **Independent Variables** constituted smallholder dairy farmers' **perceptions** of climate changes and climate change effects in the study area, their**socio-demographic characteristics**, **knowledge** of climate change and climate change effects, and **sources of information** on climate change and climate change effects. These sets of independent variables would have a relationship with **climate change adaptation**(Dependent Variables) by the smallholder dairy farmers of the study area. In this study, smallholder dairy famers' climate change adaptation (Dependent Variable) was measured in terms of farming types; production method; types of breeds of dairy cattle (pure of cross breeds); adaptability of the breeds of dairy cows kept; fodder source; main source of farm labour; number of dairy cows kept; and trend in income from the dairy enterprise. The last measure (trend in income from the dairy enterprise) was considered the ultimate measure of climate change adaptation by smallholder dairy farmers of the study area.

Nevertheless, there is another set of variables, known as the **Moderator Variables**, that were not controlled in this study, but which would modify the nature and extent of the relationship between the Independent Variables and the Dependant Variable. These Moderator Variables in this study included: **Government Policy** (on extension, climate change, marketing of dairy products, etc.); **Infrastructure** (e.g. rural road network, electricity, water supply, market infrastructure, mobile phone connectivity, etc.); **Security of Land Tenure**; **General Security**; **Health of the household**; and **Market forces of demand and supply**. These relationships are summarized in Figure 2.

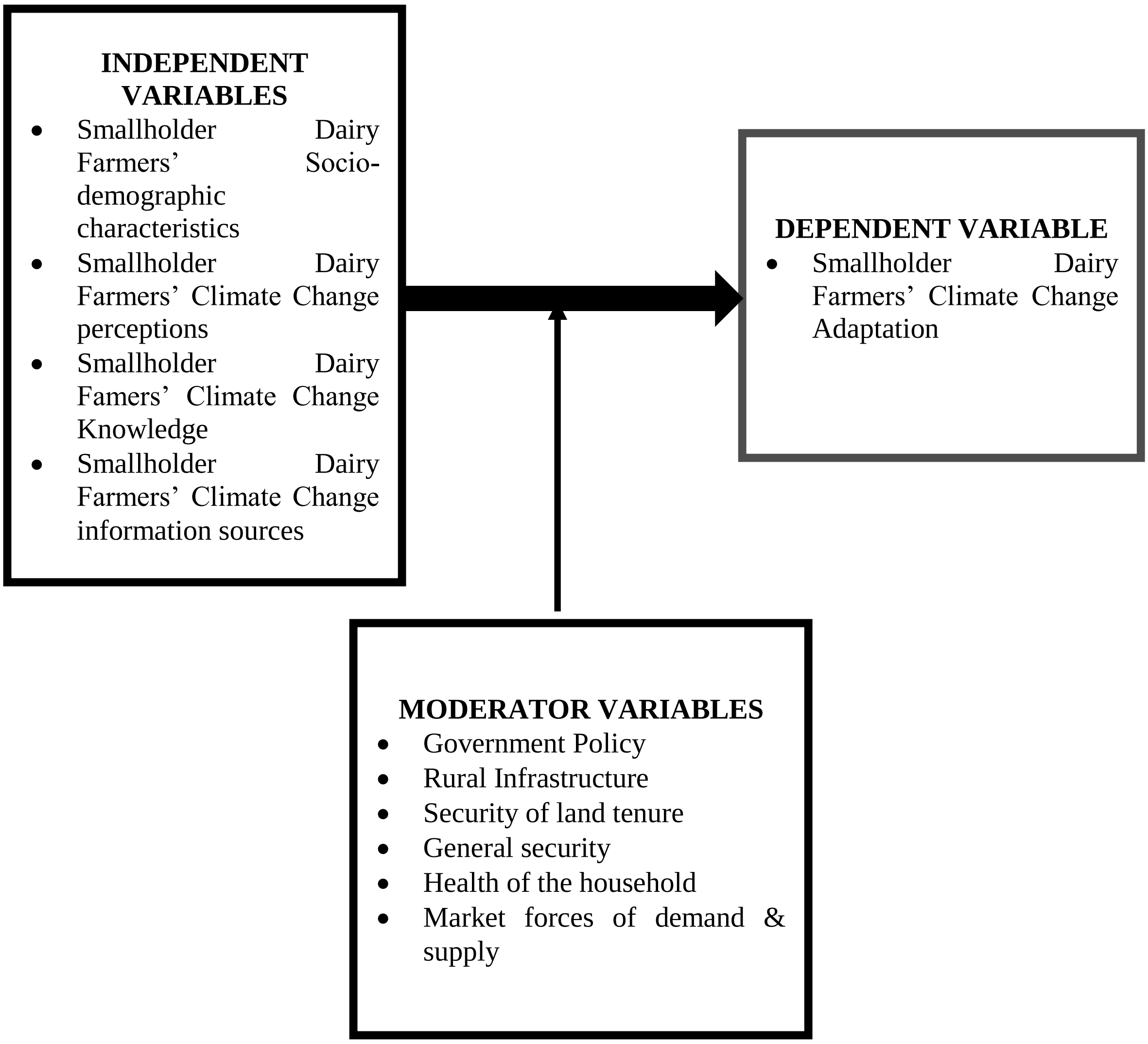

Figure 2: The conceptual framework showing the relationships between the study variables
(Source: Adapted from Mugenda & Mugenda, 2003)

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This Chapter provides a description of the methodology that was applied for this study. Section 3.2 gives a description of the Study Design. Section 3.3 describes the Study Site. Section 3.4 describes the study population and sampling. Section 3.5 describes data collection methods and procedures, while Section 3.6 looks at data quality in terms of instrument validity and reliability, as well as data entry and transcription. Section 3.7 describes data analysis methods as per the study objectives, while Section 3.8 describes the ethical considerations for the study.

3.2 Study Design

This cross-sectional study took a correlation design (Formplus, 2020) employing *Concurrent Fixed Mixed Methods (*Schoonenboom & Johnson, 2017*)* with equal weight being given to both quantitative and qualitative approaches of data collection and analysis. Based on the study objective, qualitative data had to be collected to triangulate and validate findings from quantitative study (Schoonenboom & Johnson, 2017). The unit of sampling was the household, and within the household, the household head was the study respondent.

In this study, data was collected from the study respondents once, without the option of the respondents being followed later for collection of the same data. This explains why it was a *cross-sectional* and not a longitudinal study (McCombes, 2020), as in most of the Educational studies. Scholars (Mugenda & Mugenda, 2003; Formplus, 2020) state that *Correlational* studies are used to describe relationships between variables; with results being used to indicate either *positive relationship, negative relationship, or no relationship at all.*

In this study, attempts were made to establish relationships (if any) between the independent variables of study (smallholder dairy farmers' socio-demographic factors, perceptions of climate changes; knowledge of climate change effects in their region; and sources ofclimate change information) and the dependent variable (climate change adaptation).By nature of the study objectives, the study's independent variables, and the fact that the study sought to establish relationships (if any) between them and the dependent variable; in this study the use of both *quantitative* and *qualitative* approaches of data collection was chosen *beforehand,* and not by virtue of issues that arose in the course of conducting the study. This was the basis of adopting a **"Fixed"** Concurrent Mixed Approach as opposed to an "Emergent" one (Schoonenboom & Johnson, 2017).

3.3 Study Site

The study was conducted in Migori County (See Map of Study Site in Appendix II), which is located in the South western Kenya between latitude 1^o 24' South and 1^o 40'South and Longitude 34^o East and 34^o 50'East. The County borders Homa Bay County to the North, Kisii and Narok counties to the East, and the Republic of Tanzania to the South. It also borders Lake Victoria to the West; and covers an area of 2,613.5 km^2 including approximately 478 km^2 of water surface (GoK, 2019a). The County comprises eight (8) sub-counties, namely: Rongo, Awendo, Uriri, Suna East, Suna West, Nyatike, Kuria West, and Kuria East. Four sub-counties namely Rongo, Awendo, Uriri, and Kuria West were selected for the study because they present a fairly homogenous climate, which also make them the dairy belt of the County. Within the four sub-counties, the study was confined to agro ecological zone LM_2, except in Rongo, where it was undertaken in UM_2(GoK, 2019b).

Migori County has an inland equatorial climate modified by the effects of altitude, relief and Lake Victoria. Rainfall is generally continuous with little distinction between first and second rains. Annual rainfall averages between 700 mm and 1,800 mm. The first peak season comes over the months of March to May, and is reminiscent of the long rainy season; while the second peak season that is reminiscent of the short rains comes over the period of September-November. The two peaks are separated by a three-month period each, of June-August and December-February (GoK, 2019b). Precipitation received over the short rainy seasons in Migori County is on the increase, sometimes even being more reliable, well distributed and higher in amounts and spread (spatial and temporal) compared to the long rainy seasons (UNDP, 2012). On average February is considered the driest month, while April is the wettest month. Temperatures show mean annual minimum of 24^{o}C and maximum of 31^{o}C, with a diurnal range of about 7^{o}C, relatively high humidity ranging between 40% and 95% (depending on season) and a potential evaporation of 1800 mm to 2000 mm per year (GoK, 2019b).

The study site produced 9,256,554kg of milk in 2019 (Table 4), for a population of 591,838 people (GoK, 2019b). Given that each person requires 100kg of milk annually (Abayomi, 2013); Migori County is generally a milk deficit county, as the total annual milk requirement for 591,838 people would be 59,183,800kg annually. This leaves a deficit of 49,927,246kg; which the county has to meet through imports from neighbouring counties.

The county is predominantly into sugarcane production. However, in the four study sub-counties, smallholder dairy farming is rapidly gaining prominence. Land holding among the smallholder dairy farmers in the study site is 3 acres on average, with the farmers practicing mixed crop and dairy farming. A mix of stall-feeding (mainly at night and during milking) and tethering of the dairy herd to graze within the homesteads, or in paddocks is common; with crop residues being used to substitute commercial feeds. Characteristically the smallholder dairy farmers of the study area keep cross-bred cattle, and depend largely on fodder from own farm, while a few lease land for fodder or buy fodder from neighbours (GoK, 2019b). Most of the smallholders depend on water from the rivers, such as Kuja, Migori, Riana, Ongoche, and Sare (GoK, 2018). While some have sunk own shallow wells for watering the dairy cattle and for domestic use, others supplement with rain water harvesting (mainly in the form of roof catchment). The study was conducted only among the smallholder dairy farmers with at least 10 years' experience in dairying.

3.4 Study Population and sampling

Records from Migori County Livestock Production Office indicated that the number of smallholder dairy farmers in the four sub-counties was 2,528 (GoK, 2013; Bosire *et al.*, 2019). It is from these that a sample was drawn for the study using Yamane's Formula (Taro, 1967) for small populations less than 10,000 as follows:

$$n = \frac{N}{1+N\ (e)^2} \qquad \textbf{Equ. 1}$$

Where:

n = the desired sample size (for target populations less than 10,000);

N =the population size;

e = the level of precision or statistical significance set;

Therefore, given population of 2,528 smallholder dairy farmers in the selected agro-ecological zones (UM_2 and LM_2) of study within Migori County, for measurement at $p<0.05$, the desired sample size was:

$$n = \frac{2{,}528}{1+2{,}528\ (0.05)^2}$$

=345.355 (≈ 345 smallholder dairy farmers)

The study was conducted among 367 smallholder dairy farmer households proportionately distributed among the four sub-counties as shown in Table 1. As Table 1 indicates, majority of the study respondents were drawn from Rongo Sub-county, which has the largest number of smallholder dairy farmers, the contrast of which is true for Awendo Sub-county that has the lowest number of smallholder dairy farmers.

Table 1: Sample size for the study

Sub-county	Number of Smallholder Dairy Farmers	Desired sample Size	Actual sample size
Rongo	1,480	222	232
Awendo	88	13	13
Uriri	510	77	77
Kuria West	450	68	45
Total	**2,528**	**380**	**367**

Multi-stage sampling was used to obtain the sample (Figure 3). First, a visit was made to the sub-county livestock offices, from which a listing of all smallholder dairy farmers in each of the wards was obtained. Then, proportions of farmers in each of the wards were determined based on the populations listed. The same were used to distribute the desired sample size of 380 (adding 10% to 345 to take care of non-respondents) within the each of the wards.

Within each ward, the number of villages where smallholder dairying was being practiced was determined and proportionate sampling was again used to assign the number of farmers per village. Within each village, simple random sampling was used to pick households for inclusion into the study. On the other hand, for qualitative study, participants were identified and picked by purposive sampling, based on their role and level of involvement in smallholder dairying and meteorology. The sampling procedure is summarized in Figure 3.

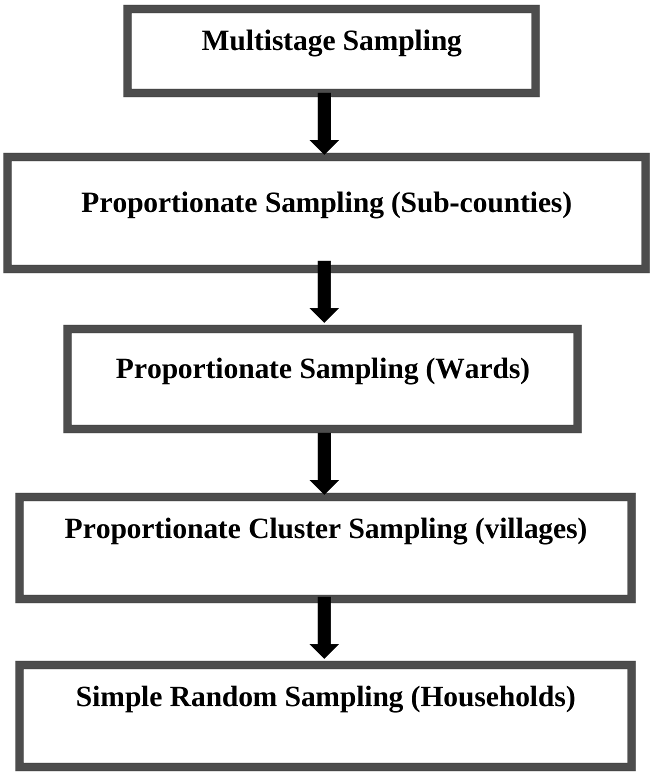

Figure 3: Schematic presentation of the study's sampling procedure

3.5 Data Collection

Secondary data was obtained by review of reports and documents and from literature obtained from the internet and from government offices, research stations (KALRO and Department of Meteorology) using a data checklist (Appendix VIII). The data collected included dairy population of the four sub-counties of study as well as socio-demographic and dairy production profiles of smallholder farmers within the study area. Other secondary data collected included temperature and precipitation data, as well as trends in milk production, demand and sales in the four sub-counties of study.

Quantitative primary data was digitally collected using an open data kit (ODK) software. A structured household survey questionnaire (Appendix III) was used to obtain primary quantitative data from heads of smallholder dairy households with at least 10 years' experience in dairying. The questionnaire sought to establish the challenges posed to the smallholder dairy farmers by climate change and the effects these had on smallholder dairying (categorized as high, medium or low effect). Multiple responses were accepted. It also sought to understand the respondents' adaptive strategies to climate change, which was defined by the farming type adopted (whether mixed dairy and crop or pure dairy farming); the production method employed (whether intensive or non-intensive); the major source of fodder (whether own or purchased); and the type of breeds kept (whether pure or non-pure). The other variables defining adaptive strategies included; the dairy breeds kept (whether Friesian and its crosses, or Non-Friesians and their crosses); the number of dairy cattle kept (Whether 2+ or less than 2); the main source of farm labour (whether household or non-household); and the observed trend in income from dairying (whether increasing or decreasing trend from milk sales). Further, the questionnaire sought to understand the smallholder dairy farmers' reasons for adopting these adaptation strategies and their level of satisfaction with farm labour and observed trend in monthly income from sale of milk from dairy cattle.

The questionnaire also captured aspects of smallholder dairy farmers' socio-demography (gender, age, marital status, educational level, household size, and experience in dairying) with a view to relating them to their climate change adaptation. Further, the questionnaire considered respondents' perceptions of observable changes in climate with respect to temperature and rainfall. It also had a set of 15 questions capturing knowledge measures on aspects of climate change and climate change effects on smallholder dairying. This tool was customised and adopted from farmer-based soil health scorecard as advocated for by Roming *et al*., (1996). It is subjective, though, assuming that the farmer who has been in smallholder dairying business for some time ought to have a grasp of certain basic concepts relating to issues in the industry, including emerging challenges like Climate Change. Finally, the questionnaire instrument had questions on sources and types of support respondents got to enable them adapt to climate change, and seeking to establish respondents' satisfaction with services from climate change information sources and what could be done to improve the usefulness of the information from the same.

On the other hand, key informant interview (KII) guide (Appendix IV) and Focus Group Discussion (FGD) guides (Appendices V and VI) were used to collect primary qualitative data from individuals and groups perceived to be experts and opinion leaders on climate change. Key informants included heads of key government parastatals and departments (of meteorology, environment, livestock production, cooperatives, and a key government livestock production farm), leadership of a dairy cooperative society and dairy farmer groups, and climate change livestock research experts from Kenya Agricultural and Livestock Research Organization (KALRO)-Kisii Station. Focus group discussions were conducted with elders (men and women) aged over 60 drawn from Kuria and Luo communities in Migori County; members of a Dairy Farmers' Cooperative Society, and select dairy farmer groups in Migori County. The proceedings of KIIs and FGDs were recorded using a digital recorder and transcribed verbatim after listening to the recordings several times.

In addition, Photography, Non-participant Observation Guide (Appendix VII), farm visits and transect walks were used to collect additional information for the study and were useful in providing further insights on the nature and extent of climate change effects in the study site. The information was collected using a camera, recorder, and by note taking.

Use of *Concurrent Fixed Mixed Methods* allowed for generation of rich information for indicator assessment; with qualitative data being collected to triangulate individual household survey data for the purpose of validating the extreme results. This, together with non-participant observation and use of secondary data enhanced the process by assuring internal and external validly of the results.

3.6 Data Quality

3.6.1 Instrument Validity

To ensure that the data collection tools (Household Survey Questionnaire; KII, FGD and Observation guides; and Secondary data collection checklist) accurately measured the variables of interest to the study, each of the items in the instruments were discussed with the peers and research supervisors from Maseno University, in relation to the study objectives. Attention was given to ensure that each of the specific study objectives was captured in the instruments, with modifications being made was deemed necessary.

3.6.2 Instrument Reliability

To ensure consistency of the questionnaire, the tool was pretested using a random sample of thirty-three smallholder dairy farmers with at least ten years' experience in the dairy industry, drawn from Kamagambo Central Location of Rongo Sub-county. The Sub-county was one of the 4 to be studied, presenting fairly similar and typical socio-economic conditions as for the rest of the study sites; but the particular Location has a high number of dairy farmers, allowing for non-inclusion of the farmers used for pre-test into the actual survey. Moreover, to minimize diffusion, a 3-month period between the pre-test and actual data collection was allowed.

Kathuri & Pals (1993) indicate that the smallest number that can yield meaningful results on data analysis in a survey is twenty (20), while other researchers (Perneger *et al*., 2014)recommend a sample size of at least thirty (30). Therefore, the number thirty-three (33) is higher than the minimum recommended number for pre-test samples. The pre-test data was then subjected to Cronbach's alpha reliability test for internal consistency; where alpha (α) is calculated using the standardized Cronbach's alpha formula of:

$$\boldsymbol{\alpha = N.c/v + (N-1).c} \qquad \textbf{Equ. 2}$$

Where:

α = the reliability coefficient;

N = the number of items in the instrument;

c = the average inter-item covariance among the items;

v = the average variance

The advantage of the Cronbach's alpha analysis procedure is that it gives both inter – and intra – item correlations (i.e. consistency) between the items being measured. A reliability coefficient of $0.60<\alpha<0.70$ is usually considered reasonable and acceptable for social studies of this nature (Santos & Reynaldo, 1999).

Accordingly, Cronbach's alpha test was run to determine the overall reliability coefficient for a set of key independent and dependent variables to be assessed in the regression model of the study. The test results are presented in Table 2. The results indicate that Cronbach's alpha is **0.705** and **0.906** for perception of climate changes and adaptive strategies to effects of climate change in Migori County**,** respectively. The two combined gave an overall reliability coefficient of **0.847,** which indicates a high level of internal consistency for our scale with this specific sample, hence; adequate to proceed with the inferential statistical analysis.

Table 2: Reliability statistics for Cronbach's Alpha Test for climate change perceptions, adaptive strategies and combination of both (n=33)

Parameter	**Cronbach's Alpha**	**Cronbach's Alpha based on Standardized Items**	**No. of items**
Climate change Perceptions	0.705	0.530	16
Climate change adaptive strategies	0.906	0.905	13
Climate change perceptions & Adaptive strategies	0.847	0.772	29

Using the rule of George & Mallery (2010), a reliability coefficient above 0.9 implies excellent; above 0.8 is good; above 0.7 is acceptable; above 0.6 is questionable; above 0.5 is poor; while that below 0.5 is unacceptable. Thus, the reliability for both individual items (0.705 and 0.906) and the overall reliability (0.847) were between the acceptable and excellent levels.

3.6.3Data entry and transcription

Digital data collection using an open data kit (ODK) software ensured that as data was being collected from each of the sub-counties of the study site, it was directly being registered in a central repository (server). This made it was easy to clean data from each of the sub-counties before finally accepting only cleaned data into the server for analysis. Moreover, use of digital data collection eliminated use of bulky paper questionnaires that would be subject to destruction in cases of adverse weather conditions. Together with training and pre-test, it also ensured standardization of the administration of the tool, thereby greatly reducing errors due to misunderstanding of the questions on the basis of its framing (not on the basis of the one asking it).

On the other hand, transcription of the digital voice recordings from KIIs and FGDs was carefully done, with the transcribed data (in excel spreadsheet) being carefully compared with the voice recordings and notes taken during the discussions to minimize data loss.

3.7 Data Analysis and Presentation

Quantitative data obtained from the survey was coded, entered and analysed using IBM Statistical Package for Social Sciences (SPSS) for Windows, Version 20.0, as per the study objectives. Descriptive statistics, including frequencies, percentages, range (minimum and maximum values), means, and standard deviations were used to organise and describe the data. Inferential statistics including Factors analysis (Principal Component Analysis), Binary Logistic Regression, and In-silico one-proportion Z score test, as per the study objectives; with results presented at $p < 0.05$(see Table 3). For qualitative analysis, *Framework* Approach was used for all objectives, except for Objective 5, where *Content* Analysis Method was employed.

3.7.1 Data Analysis for Assessing level of adaptation to climate change among smallholder dairy farmers

Quantitative data obtained from the survey was organized into percentages to show the effects of climate changes on smallholder dairying and the adaptive strategies employed by study respondents to climate change effects. The data was then subjected to a Principal Component Analysis (PCA), to identify factors that influence smallholder dairy farmers' adaptation to climate change effects (i.e. mixed farming, non-intensive production system, own fodder, non-pure breed of dairy cattle, non-Friesians and their crosses, 2 dairy cattle and above, household is main source of labour, and increasing trend in income from dairying). The factors that had the highest proportionate influence, based on the Eigen values (accounting for 75% of the influence) were then determined. Finally, one proportion Z-score test for proportions was used to test for significant difference between the means of the climate change adaptation measures and the presumed mean (assuming that 50% of respondents would adapt and the other 50% would not), so as to confirm if the differences were significant ($p<0.05$) as per the equation below:

$Z_i = \frac{x_i - x}{s}$ **Equ. 3**Where;

Zi= Z-score for an attribute *i*;

xi=observed mean for an attribute *i*;

x = sample mean;

s =sample standard deviation.

Qualitative data (KIIs and FGDs) was first transcribed from the voice recordings into word. The word version was then entered into an excel spread sheet and analysed using the *Framework Approach*. This approach is used to organize and manage data by summarization, resulting in a robust and flexible matrix output, which allows for analyzing data both by case and themes. In the analysis, data is sifted, charted and sorted in accordance with key issues and research themes using five steps: familiarization; identifying a thematic framework; indexing; charting; and mapping and interpretation.

3.7.2 Data Analysis for Influence of Socio-demographic characteristics on smallholder dairy farmers' climate change adaptation

Socio-demographic factors were subjected to descriptive statistical analyses to determine percentages, minimum and maximum values, means, and standard deviation of respondents for various variables. Binary logistic regression analysis was then undertaken to determine whether there was any significant relationships between smallholder dairy farmers' socio-demographic characteristics and their adaptive strategies to climate change effects. Each of the eight measures of adaptation to climate change effects was run against each of the six socio-demographic characteristics singly and then jointly; with findings being presented at $p<0.05$. This yielded odds ratios of the significant relationships between socio-demographic factors of smallholder dairy farmers and their adaptive strategies to the effects of climate change in the study area.

The general regression equation in this case models the log odds of a binary outcome, *y* (adaptive strategy) as a function of predictor *x* (smallholder farmers' socio-demographics) was used and is presented as:

$$ln\left[\frac{p}{1-p}\right] = \beta 0 + \beta 1x1 + \beta 2x2 + \cdots + \beta nxn \qquad \textbf{Equ. 4}$$

Where:

p = proportion (probability) of *y*=1, and

*x*1-*xn* = the predictor socio-demographic characteristics of sex, age, marital status, highest educational level, household size, and experience in dairy farming (with *n*=6)

β0=The*log* odds of a smallholder dairy farmer being perceived to be an adopter of adaptive strategies to climate change effects (when xi =0) and

β1-n= The *log* odds of a smallholder dairy farmer being perceived to be an adopter of adaptive strategies to climate change effects (when *xi* =1-6).

3.7.3 Data Analysis for Relationship between smallholder dairy farmers' climate change perceptions and climate change adaptation

Survey respondents' perceptions were analysed using descriptive statistics, including percentages and frequencies. Binary Logistic Regression Analysis Method was used to establish relationships between survey respondents' perceptions and climate change adaptations they adopted. The general regression model (Equation 4), which in this case models the log odds of a binary outcome, *y* (adaptive strategy) as a function of predictor *x* (smallholder farmers' perceptions of climate changes); only that now *n*=19 (i.e. we have *x*1-19 and β1-19) was used. *FrameworkAnalysis* Method was used to analyse the findings from qualitative study (KIIs and FGDs).

3.7.4 Data Analysis for Relationship between climate change knowledge and smallholder dairy farmers' climate change adaptation

For each respondent, their responses to each of the 15 knowledge measures was marked against the standardized marking scheme to give an overall score. The scores (out of 15) were then converted into percentages to indicate the level of knowledge of the study respondents on climate change effects on smallholder dairy farming. Based on the percentage score, respondents were grouped into 2 categories. Those with scores below 50% were grouped as having low knowledge of climate change effects, while those with scores above 50% were categorized as having high level of knowledge on climate change effects. To show relationships between the level of knowledge of respondents on climate change effects and their adaptive strategies to climate change, Binary logistic regression analysis was used. In this regard, each of the 15 questions on knowledge formed a knowledge measure (independent variable), while each of the eight climate change adaptive strategies became the dependent variable.

The general regression equation (Equation 4) which in this case models the log odds of a binary outcome, *y* (adaptive strategy) as a function of predictor *x* (smallholder farmers' knowledge of climate change effects); only that now n=15 (i.e. we have x1-15 and β1-15) was used. Results were then presented at $p<0.05$. Qualitative data from FGDs was analysed using the *Framework Approach*.

3.7.5 Data Analysis for Relationship between institutional support and smallholder dairy farmers' climate change adaptation

Quantitative data was analysed using descriptive statistics (frequencies, percentages and rankings) to show the extent to which the study respondents depended on the various sources of information relating to climate change and its effect on smallholder dairying. The sources of information on climate change and climate change effects from the survey were coded according to types for ease of analysis. Binary logistic regression analysis was used to determine relationships between the available farmer advisory services and the smallholder dairy farmers' adaptive strategies to climate change effects in the study area; and whether such relationships were significant. The general regression equation (Equation 4) which in this case models the log odds of a binary outcome, *y* (adaptive strategy) as a function of predictor *x* (smallholder farmers' source of information on climate change and its effects on dairying); only that now n=3 (i.e. we have x1-3 and β1-3) was used. Results were presented at $p<0.05$. Qualitative data (KIIs and FGDs) was analysed using *Content Analysis Approach*. The sources of climate change information available to farmers was used to provide a basis for explaining the level of respondents' adaptation to climate change effects.

Table 3: Summary of Data Analysis Procedures

No.	Hypotheses	Independent Variables	Dependent Variables	Statistical Analysis
H_{O1}	Level of adaptation to climate change among Smallholder dairy farmers of Migori County-Kenya is not significantly high	Actual means of adopters	Assumed mean(0.05)	Frequencies & Percentages (for climate change effects on smallholder dairying and technology adoption)
				In-silico one proportion Z-score
H_{O2}	Socio-demographic characteristics of Smallholder dairy farmers of Migori County-Kenya has no statistically significant influence on their climate change adaptation.	Socio-demographic characteristics of smallholder dairy farmers of Migori County-Kenya	Climate change adaptation of Smallholder dairy farmers in Migori County-Kenya	Descriptive Statistics (Frequencies, Percentages, Means, Range, &Standard deviation).
				Inferential Statistics

				(Binary Logistic Regression)
H_{O3}	There is no statistically significant relationship between climate change perceptions of Smallholder dairy farmers of Migori County-Kenya and climate change adaptation.	Perception measures	Climate change adaptation ofSmallholder dairy farmers in Migori County-Kenya	Inferential Statistics (Binary Logistic Regression)
H_{O4}	There is no statistically significant relationship between climate change knowledge of smallholder dairy farmers of Migori County-Kenya and their climate change adaptation.	Knowledge measures	Climate change adaptation of Smallholder dairy farmers in Migori County-Kenya	Descriptive Statistics (Frequencies &Percentages)
				Inferential Statistics (Binary Logistic Regression)
H_{O5}	There is no statistically	Climate	Climate	Descriptive

	significant relationship between Smallholder dairy farmers of Migori County-Kenya's institutional support and climate change adaptation.	change information sources	change adaptation of Smallholder dairy farmers in Migori County-Kenya	Statistics (Frequencies & Percentages)
				Inferential Statistics (Binary Logistic Regression)

3.8 Ethical considerations

The researcher obtained requisite clearance from the School of Graduate Studies of Maseno University as well as Ethical Approval from the Ethics Board of Maseno University and the Research Permit from the National Council of Science, Technology and Innovations (NACOSTI) before commencing the study. Assistance was sought from Migori County Director for Livestock Development for endorsement of the study to be undertaken within the county, and for support with access to secondary data from both the county and sub-counties of study.

With the support of sub-county staff of the Department of Livestock Development, study respondents were identified. Due appointments were made with each category of respondents, with the survey instrument being administered to the respondents face-to-face. Before commencing the study (for both quantitative and qualitative aspects), informed consent was sought from each and every respondent. After introductions and the purpose of the study, the respondents were informed that the study would take the form of a discussion. The study aspects around which the discussions would take place were explained, and the stipulated duration for the discussion. It was explained to the respondents that they would be free to choose to give their views or not on any of the aspects. Confidentiality of the information provided was assured, with respondents being informed of the use of the data gathered; and how the respondents would directly or indirectly benefit from it. Participation in the survey was purely on free volition, and the respondent would be free to decline to participate, continue to the end of the survey, or withdraw mid-way. The discussion only continued with respondents who accepted to freely participate in the study.

Aspects of the study findings (objectives 1 and 2) have been published in the Atmospheric and Climate Science (ACS) Journal of the United States of America (Appendix I), with other aspects expected to be published in refereed journals in two years' time. Feedback sessions will be organized with a cross-section of the study respondents and other stakeholders in climatology and smallholder dairy farming to ensure that findings of the study could help improve the performance of smallholder dairy industry in Migori County and beyond. Fliers and brochures will be used to ensure that a large number stakeholders gain access to the information. Copies of the thesis from the study will also be presented to Maseno University Main Library; Migori County Office for Livestock Development and the National Council for Science, Technology and Innovation (NACOSTI) for reference.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

In this Chapter, findings of the study are described and discussed by objective. Section 4.2 presents findings and discussions on Smallholder dairy farmers' Climate Change adaptation. Section 4.3 presents findings and discussions on the Influence of socio-demographic characteristics on smallholder dairy farmers' Climate Change adaptation. Section 4.4 presents findings and discussions on Climate Change perceptions and smallholder dairy farmers' adaptation. Section 4.5 presents findings and discussions on Smallholder dairy farmers' knowledge and Climate Change adaptation; while Section 4.6 presents findings and discussions on Institutional support and smallholder dairy farmers' Climate Change adaptation.

4.2Smallholderdairy farmers' climate change adaptation1

4.2.1 Results

4.2.1.1 Human and diary population and production statistics

Table 4 presents a summary of the demographic profile and dairy population of the study site. Table 4 shows that Rongo Sub-county had the highest dairy cattle population (3,458), while Awendo Sub-county had the lowest dairy cattle population (840). Ironically, Kuria West Sub-county had the highest earnings from milk sales in 2019 (Ksh. 220, 179,120), while Awendo Sub-county had the least earnings from milk sales in 2019 (Ksh. 8,523,360).

[1]Findings of this objective have been published in *Journal of Atmospheric and Climate Sciences*, Vol.9, No. 3, pp. 456-478 (July, 2019). http://www.scirp.org/journals/acs. ISSN Online: 2160-0422; ISSN Print: 2160-0414.

Table 4: Summary of demographics and dairy population in study site

Sub-county	Human Population (2019)	Farm families (2019)	Av. Family size (2019)	Dairy Cattle (2019)	Milk Production in kg. (2019)	Price/kg. (Ksh).	Earnings from Milk sales in Kshs. (2019)
Uriri	141,448	30, 094	4.7	2,038	2,382,314	70	166,761,980
Awendo	117,290	27,033	4.3	840	142,056	60	8,523,360
Rongo	124,587	29,087	4.3	3,458	3,062,532	60	183,751,920
Kuria West	208, 513	39,781	5.2	1,371	3,669,652	60	220,179,120
Total	**591,838**	**125,995**	**4.6**	**7,707**	**9,256,554**		**579,216,380**

Source: GoK 2019a&b.

4.2.1.2 Evidence of climate change

Figure 4 presents the mean minimum and maximum temperature for Migori for 35 years (1982-2015). Generally, changes in solar radiation would be good predictors of climate changes taking place in any place, and mean minimum temperature is even a better measure of climate changes of any place (Sivaramanan, 2015). Figure 4 shows that generally, the mean minimum temperature for Migori has had a general trend of steadily increasing between 1982 (when the mean minimum temperature was 15.8^{o}C) and 2015 (when the mean minimum temperature was 17.3^{o}C), with even higher values being registered in-between. Thus, generally, the mean minimum temperature rose by about 3^{o}C. Regarding maximum temperature, Figure 4 shows a general trend of increasing men maximum temperatures for Migori, from 28.1^{o}C in 1982 to 28.5^{o}C in 2015; with higher values being recorded in-between. This present a rise of about 0.4^{o}C in mean maximum temperature over the period; with much higher increases in maximum temperature being experienced in Migori since 1986.

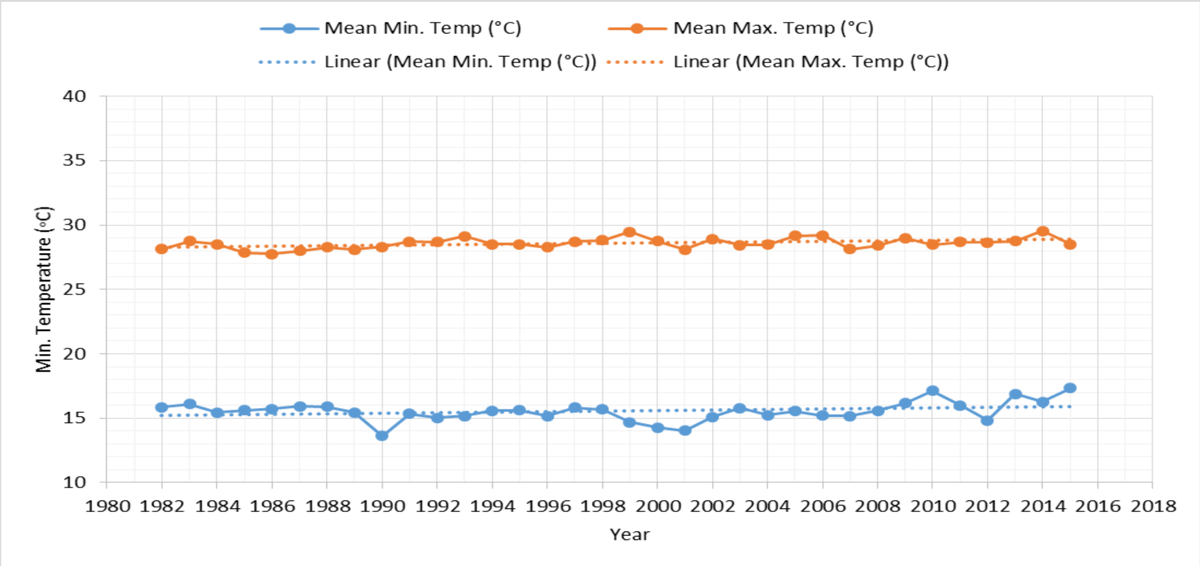

Figure 4: Mean minimum and maximum temperature trend for Migori (1982-2015)

Figure 5 presents the mean annual rainfall data for Migori County (1980-1994 and 1999-2013). Figure 5 shows that, despite missing data (1995-198), generally there has been increases in mean annual rainfall for the study area between 1980 (when the mean annual rainfall was 1,523.90 mm) and 2013 (when the mean annual rainfall was 1,806.20 mm), with even higher increases being recorded in between. This presents an increase of about 281.3 mm in terms of mean annual rainfall over the period.

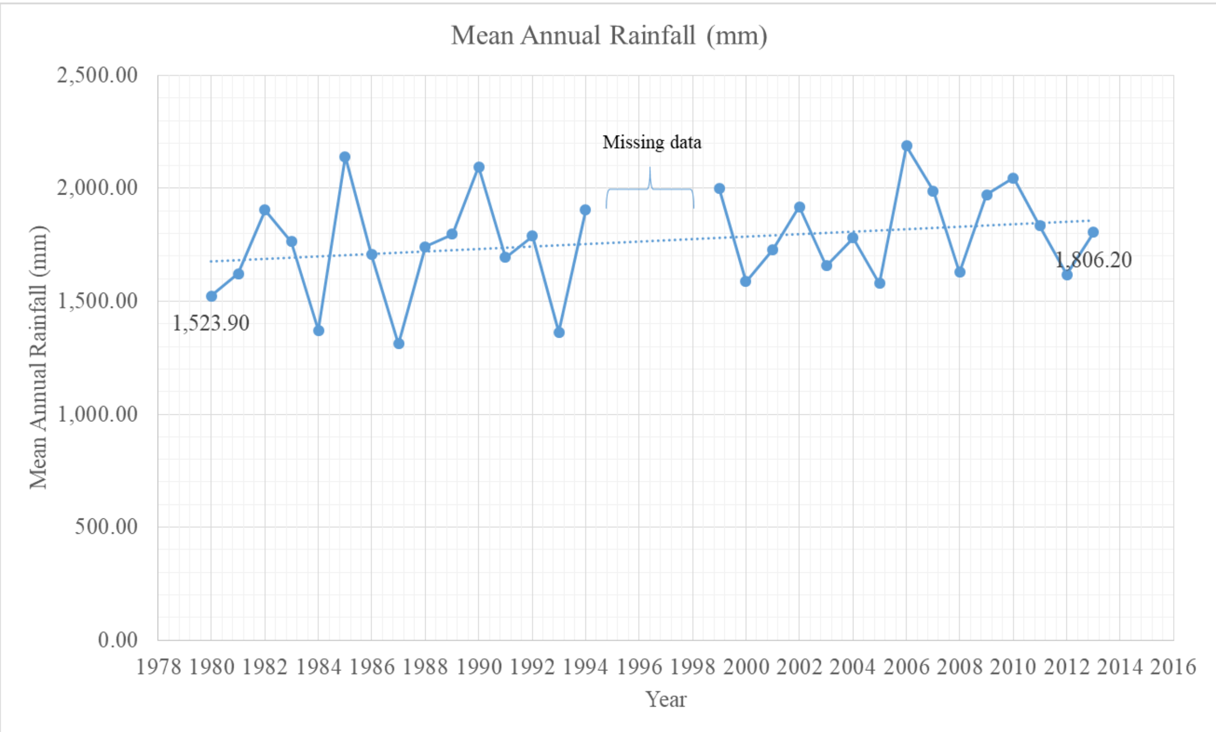

Figure 5: Mean annual rainfall trend for Migori (1980-2013)

Figure 6 shows the rainfall trend over the period 1980-2013, but also indicates the trend in terms of monthly rainfall data for 1980-1994, and 1999-2013 (rainfall data was missing for the period 1995-1998). Figure 6shows that the mean annual rainfall (mm) received in Migori County fluctuated over the period 1980-2013, but have generally shown a slight increment over the period. Secondary data obtained from Lake Victoria Observing System (LVOS, 2013) further indicate that rainfall amounts have been steadily increasing in the region of Migori over the period 1980-2013. This has resulted into flooding of rivers Kuja and Migori, displacing residents of Nyatike Sub-county almost annually over the long rainy seasons since the year 2000. The emerging rainfall pattern is that of rainfall throughout the year, with two peaks from March to May and August to November. Further, the pattern indicates that the area has not suffered from any serious drought, apart from rainfall distortions (LVOS, 2013).

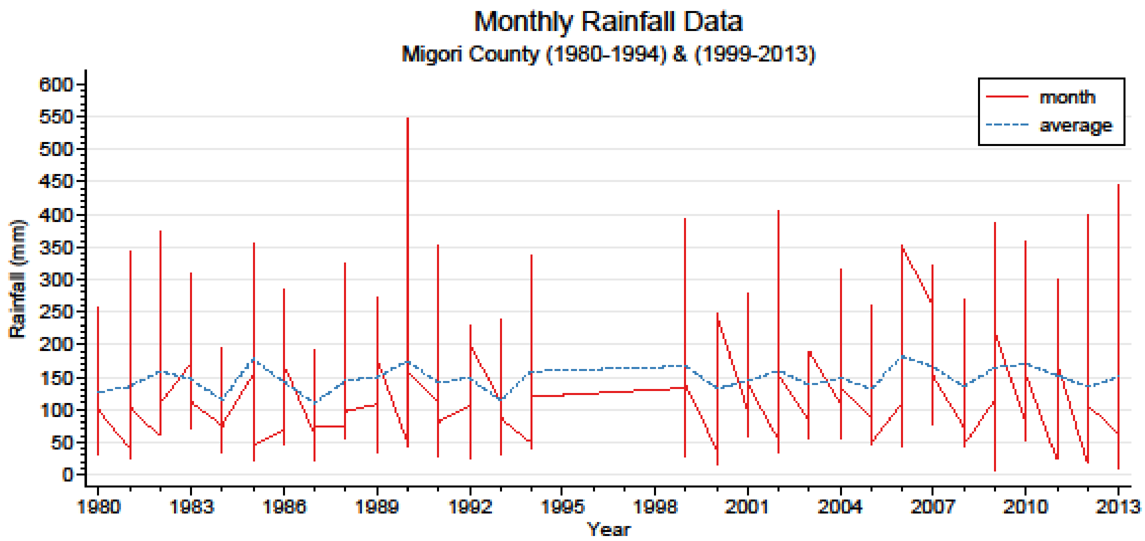

Figure 6: Changes in rainfall for Migori County (1980-1994 and 1995-2013)

4.2.1.3Effects of climate change on smallholder dairy systems

The study established that climate changes have had moderate to high effects on the performance of the smallholder dairy industry within the County (Table 5). The survey established that climate changes with high effects experienced by smallholder dairy farmers in Migori County include: increase in diseases and pests (61.3%; n=367); pasture loss (43.6%; n=367); over grazing of land (41.7%; n=367); and under feeding of livestock (40.0%; n=367). Those with moderate effect included: increased labour demand (43.6%; n=367); poor quality products (42.8%; n=367); reduced milk production (41.4%; n=367); loss of livestock (40.6%; n=367); water scarcity (39.5%; n=367); and drying of nearest water sources (39.2%; n=367).

Table 5: Climate change effects on smallholder dairy farming in study site (n=367)

Climate change effect	Low Effect		Moderate Effect		High Effect	
	No.	%	No.	%	No.	%
Pasture loss	115	31.3	92	25.1	160	43.6
Drying of nearest water sources	117	31.9	144	39.2	106	28.9
Loss of livestock	131	35.7	149	40.6	87	23.7
Under feeding of livestock	92	25.1	128	34.9	147	40.0
Increases in diseases and pests	42	12.5	96	26.2	225	61.3
Selling of livestock at throw away prices	132	36.0	139	37.9	96	26.1
Long walk in search of water and pasture	180	49.0	154	42.0	33	9.0
Over grazing of land	95	25.9	119	32.4	153	41.7
Poor market for the livestock products due to poor quality	84	22.9	157	42.8	126	34.3
More human labour required	56	18.8	160	43.6	138	37.6
Increase in livestock-human-wildlife conflict	141	38.4	137	37.3	89	24.3
Reduced milk production	127	34.6	152	41.4	88	24.0
Water scarcity	84	22.9	145	39.5	138	37.6

4.2.1.4 Smallholder Dairy farmers' adaptive strategies to climate change

Figure 7 shows the extent to which each of the eight parameters for measuring adaptation to climate change was adopted by the study farmers. It is evident that the smallholder dairy farmers of Migori County were highly adapted to climate change effects; with 68.4% to 96.5% of them adopting various strategies in response to climate change effects.

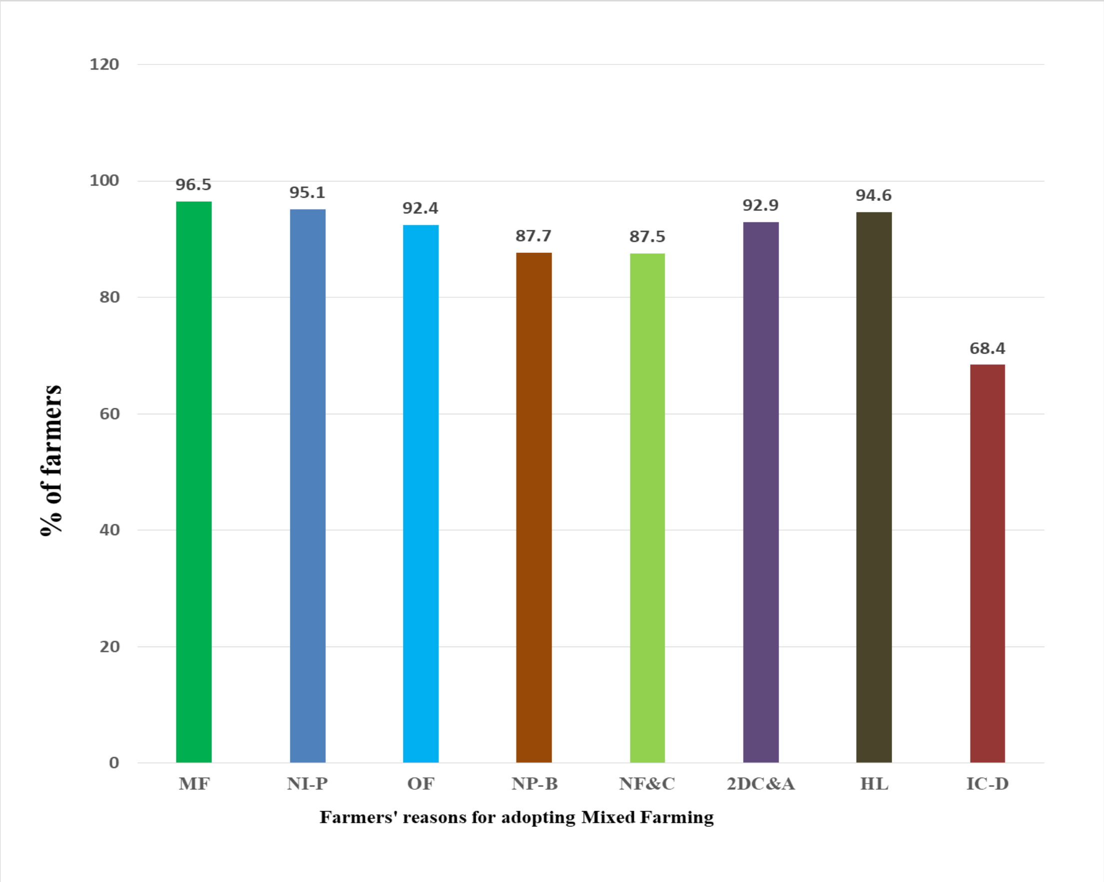

Figure 7: Distribution of respondents by climate change adaptive strategies* (n=367)

****MF= Mixed Farming; NI-P= Non-Intensive Production; OF=Own Fodder; NP-B=Non-Pure Breeds; NF&C=Non-Friesians and their crosses; 2DC&A=2 Dairy Cattle and Above; HL=Household Labour; and IC-D=Increasing trend in income from dairy***

Climate change adaptive strategies adopted by majority of the study respondents include: mixed crop and dairy farming (96.5%; n=367), non-intensive dairy farming (95.1%; n=367), use of household members as the main source of farm labour (94.6%; n=367), reducing herd size to two dairy cattle (92.9%; n=367), and establishing own fodder (92.4%; n=367). The study established that a comparatively low number of farmers (68.4%; n=367) registered increases in income from milk sales over the past 10 years.

4.2.1.5 Proportionate contributions of adaptive strategies to climate change adaptability

Eigen values of the various adaptive factors and their proportionate contribution from Principal Component Analysis (PCA) are presented in Table 6. The factors included Mixed Farming (Factor 1); Non-intensive production system (Factor 2); Own fodder (Factor 3); Non pure breed of dairy cattle (Factor 4); Adaptable breeds-Non Friesians and their crosses (Factor 5); Reduced herd size-2 dairy cattle and above (Factor 6); Household labour (Factor 7); and Increasing trend in income from dairying (Factor 8).

Table 6: Relative contribution of the adaptive factors to climate change adaptability

Factor	Eigen value	Difference	Proportion	Cumulative
Mixed Farming	1.934	0.662	0.242	0.242
Non intensive production system	1.272	0.254	0.159	0.401
Own fodder	1.017	0.096	0.127	0.528
Non pure breed of dairy cattle	0.921	0.025	0.115	0.643
Non Friesians and their crosses	0.896	0.083	0.112	0.755
2 dairy cattle and above	0.813	0.143	0.102	0.856
Household is main source of labour	0.670	0.193	0.084	0.940
Increasing trend in income from dairying	0.478		0.060	1.000

LR Test: independent vs saturated. Chi^2 (28)=226.08; Prob. >Chi^2=0.00

Three (3) factors namely, Mixed farming (Factor 1), Non intensive production system (Factor 2) and Own fodder (Factor 3) had the highest Eigen values of 1.934, 1.272 and 1.017, respectively and were the key determinants of adaptability of smallholder dairy farmers to climate change. The same were closely followed by Non pure breeds of dairy cattle and Non Friesians and their crosses, with Eigen values of 0.921 and 0.896, respectively. Cumulatively, these five factors contributed to over 75% of climate change adaptability by the study respondents.

Table 7: Interaction of determinant factors with adaptation variables

Variable	Mixed farming	Non intensive production system	Own fodder	Uniqueness
Farming Type	0.387	**0.393**	-0.167	0.668
Production system	**0.650**	0.202	-0.168	0.509
Source of fodder	-0.202	**0.574**	0.174	0.6
Breed of dairy cattle kept	**0.779**	-0.071	0.101	0.378
Decision to rear adapted cattle breeds	**0.798**	0.109	0.007	0.352
Number of dairy cattle kept	0.152	0.009	**0.879**	0.204
Main source of farm labour	0.148	-0.603	0.274	0.539
Income trend from dairying	-0.184	0.605	0.270	0.527

The uniqueness of the combination of the various sets of adaptive strategies employed by smallholder dairy farmers is presented in Table 7. Mixed farming (Factor 1) was the highest predictor of production system employed, the breed of dairy cattle kept, and a decision to rear adapted cattle breeds with factor loading of 0.650, 0.779, 0.798 and uniqueness of 0.509, 0.378, 0.352, respectively. Non intensive production system (Factor 2) was the highest predictor for choice of farming type and source of fodder with a factor loading of 0.393 and 0.574, and uniqueness of 0.668 and 0.600, respectively. Similarly, Own fodder (Factor 3) was the highest predictor of the number of dairy cattle kept with a factor loading of 0.879 and uniqueness of 0.204.

Table 8: Inter-factor correlations for climate change adaptation

Orthogonal Factor Loading based on Kaiser Guttman Correlation				
Factor	**Variance**	**Difference**	**Proportion**	**Cumulative**
Mixed farming	1.87334	0.5686	0.2342	0.2342
Non intensive productive system	1.30474	0.26033	0.1631	0.3973
Own fodder	1.04441		0.1306	0.5278
Pattern Matrix				
Variance	**Mixed farming**	**Non intensive production system**	**Own fodder**	**Uniqueness**
Farming Type	**0.4955**	0.2483	-0.1582	0.6678
Production system	**0.6946**	0.0004	-0.0913	0.5092
Source of fodder	-0.0568	**0.6272**	0.0581	0.6
Breed of dairy cattle kept	**0.7137**	-0.2438	0.2299	0.3783
Adaptability of cattle breeds to local conditions	**0.7911**	-0.0939	0.1154	0.352
Number of dairy cattle kept	0.0483	0.1261	**0.8819**	0.2041
Main source of farm labour	-0.0531	-0.5631	**0.3759**	0.5389
Income trend from dairying	-0.042	**0.6697**	0.1502	0.5272
Factor Rotation Matrix				
	Factor 1 (Mixed Farming)	**Factor 2 (Non-intensive production system)**	**Factor 3 (Own Fodder)**	
Mixed farming	0.9559	-0.2493	0.1556	
Non intensive production system	0.2712	0.9522	-0.1405	
Own fodder	-0.1131	0.1765	0.9778	

The relationship between various adaptive factors and the adaptive strategies employed by the smallholder dairy farmers are presented in Table 8. The factors being regression coefficients used to estimate the individual scores per case or row, indicate that, the farming type practiced, production method employed, breed of dairy cattle kept, and a consideration of the adaptability of the dairy cattle kept to the local conditions are all related to Mixed Farming (Factor 1). Source of fodder and the observed trend in income from sale of milk from smallholder dairying are all related to Non-intensive production system (Factor 2). On the other hand, the number of dairy cattle kept and the main source of farm labour are all related to Own fodder (Factor 3). These relationships are further affirmed in Table 9.

Table 9: Predictability of smallholder dairy farmers' adaptability to climate change

Variable	Mixed farming (Factor 1)	Non intensive production system (Factor 2)	Own fodder (Factor 3)
Farming Type	**0.29374**	0.21549	-0.17272
Production system	**0.38276**	0.03811	-0.13126
Source of fodder	0.00335	**0.48578**	0.0876
Breed of dairy cattle kept	**0.35857**	-0.13596	0.16759
Adaptability of cattle breeds to local conditions	**0.41669**	-0.02004	0.05866
Number of dairy cattle kept	-0.02068	0.13988	**0.85619**
Main source of farm labour	-0.086	-0.42337	**0.34209**
Income trend from dairying	0.00823	**0.52372**	0.17774

4.2.1.6 Establishing significance of respondents' climate change adaptation level

In-silico one-proportion Z scores for determining whether the study respondents' adaptation level was significantly high are presented in Table 10. The results indicate that for each of the 8 parameters for measuring adaptation, the two sample means (that of the assumed adaptation level (0.05) and the actual adaptation level (% adoption) were significantly different. The highest significant difference was experienced with respect to practicing mixed crop and dairy farming ($Z=17.82$; $p<0.05$), while the lowest significant difference was that for increased trend in income from dairy enterprise ($Z=7.05$; $p<0.05$).

Table 10: Z-scores for respondents' climate change adaptation level (n=367)

Parameter for measuring adaptation (x)	Adaptation level	Z-Score	C.I. (95%)
Mixed Crop & Dairy Farming	0.965	17.82	0.449-0.551
Non-intensive Dairy Production Method	0.951	17.28	0.449-0.551
Own Fodder	0.924	16.25	0.449-0.551
Non pure breeds of Dairy Cattle	0.877	14.44	0.449-0.551
Ayrshires, Guernseys, Jerseys & their crosses	0.875	14.37	0.449-0.551
2 Dairy cattle & above	0.929	16.44	0.449-0.551
Household is Main Source of Farm Labour	0.946	17.09	0.449-0.551
Increased Trend in Income from Dairy enterprise	0.684	7.05	0.449-0.551

4.2.2 Discussions

4.2.2.1 Evidence of climate change in Migori County

Increases in temperature and rainfall as evidenced from temperature and precipitation data collected for the study site for over 30 years (1980-2013) are reflective of climate change models for the Lake Victoria Region of East Africa (Song *et al.,* 2004; Osman-Elasha, 2009; Awange *et al*., 2013) and as reported in Section 4.3 and by Chepkoech *et al*., 2018 for Kakamega, Nakuru and Kajiado counties; by Bagamba *et al*. (2012), Banerjee (2015) and Tadesse& Dereje (2018) that climate change will lead to higher temperatures, altered rainfall patterns and increased frequencies of extreme events in Sub-Saharan Africa.

Scholars (Abayomi, 2013; Nhemachena *et al*., 2014; Smit & Pilifosova, 2018) allude that climate change effect could easily erode the gains a country has made in all dimensions, hence; the urgent need for policy makers to consider climate change adaptation among its vulnerable smallholder farmers. Of critical importance to enhancing smallholder farmers' adaptation to climate change is their perceptions of the changes in climate that have taken place over time and how the changes affect their livelihoods (Banerjee, 2015; Atiqual & Ahmed, 2016; Elum *et al*., 2017). Nhemachena *et al*., (2014) argued that the smallholder farmers' perceptions of climate change are informed by their own experiences of how climate change affects their livelihoods, adding that noticing climate change alone does not make smallholder farmers adapt to climate change. Thus, while the smallholder dairy farmers of Southwestern Kenya recognize that changes in climate have taken place over time, whether this recognition translates into tangible local adaptation to climate change is another issue.

Some scholars (Mwaniki, 2016; Smit & Pilifosova, 2018) have argued that argued economic, political, social, cultural, educational, and technological factors largely determine farmers' choice of climate change adaptation, and that they in-turn influence their perceptions of climate changes, although the views vary between and within regions, countries, groups, sectors, and over time. Spatial differences in climate change adaptation cannot be down-played (GEF, 2019),hence; even though this study did not make efforts to examine differences in adaptation of smallholder dairy farmers of the four sub-counties of study, it is probable that this difference exists, and could possibly be significant. Again, even though findings indicate that the smallholder dairy farmers of the study area are fairly well adapted to climate change effects ($7.05<Z<17.82$; $p<0.05$)gaps still exist (Bagamba *et al*., 2012) and it is not clear whether economic, social, political, cultural, educational, or technological factors have been the major drivers for this(Smit & Pilifosova, 2018).

4.2.2.2 Effects of climate change on smallholder dairy systems

The study established that the study area has witnessed changes both in mean minimum temperature (3^{o}C rise) and mean annual rainfall (381mm rise in annual), with distorted rainfall patterns. The changes have had direct low to high effects on the performance of smallholder dairy farming enterprise in South-western Kenya. From Table 5, the greatest effect of climate change experienced in the study area is an increase in incidences of resistant strains of parasites and diseases (reported by 61.3%; n=367), followed distantly by pasture loss (43.6%; n=367) leading to overgrazing of land (41.7%; n=367) and underfeeding of livestock (40.0%; n=367). These findings were consistent with those by Osman-Elasha (2009), Rojas-Downing *et al*.(2017), and Tadesse & Dereje (2018). Dairy production is highly vulnerable to climate change through increased temperatures and changes in rainfall patterns (Bagamba *et al*., 2012; Kirui et al., 2015; Bosire *et al.*, 2019). Such changes in ambient temperature and humidity will lead to a rise in viral and bacterial diseases, as well as parasitic infections; with animals developing increased resistance to the diseases and parasites (Tedesse & Dereje, 2018; GEF, 2020; FAO, 2020), thereby further complicating animal health management, survival, marketability of the dairy herd, and livelihoods of the smallholder dairy farmers (Odari, 2018; Tedesse & Dereje, 2018).Climate change also has an indirect effect on feed and water availability for the dairy cattle (Rojas-Downing *et al*., 2017), in that it would lead to a drop in the production and quality of the feed crop and forage, water availability and access (due to increased water demands by heat-stressed animals), as a result of increased temperatures and atmospheric carbon dioxide concentration, changes in precipitation, and a combination of these (Elum *et al*., 2017;Rojas-Downing *et al*., 2017; Tedesse & Dereje, 2018). The logical explanation for majority of study respondents (43.6%) experiencing pasture loss that is complicated by overgrazing of land (41.7%), leading to underfeeding of livestock (40.0%); is linked to the fact that climate change causes increased temperatures (Bagamba *et al*., 2012; Banerjee, 2015) that leads to diminished quantity and quality of water available for the dairy cattle (Kirui *et al.*, 2015; Rojas-Downing *et al*., 2017). With increased heat stress, the water requirements for the dairy cattle is increased, resulting in overgrazing of areas near the water points, thereby causing land degradation (Tedesse & Dereje, 2018).

Nevertheless, it is worth noting that the study site has never experienced extreme drought, as has been the case in most parts of the Sub-Saharan Africa(CIGI, 2009; FAO, 2011; Huho *et al*., 2011).

4.2.2.3 Adaptation strategies adopted by smallholder dairy farmers

The study findings (Figure 10) indicate that the smallholder dairy farmers of South-western Kenya adopted several climate change adaptation practices, including mixed crop and livestock farming (96.5%; n=367), non-intensive production system (95.1%; n=367), use of household members as the main source pf farm labour (94.6%; n=367), reducing herd size to 2 dairy cattle (92.9%; n=367), establishing own fodder (92.4%; n=367), keeping non-pure breeds (87.7%; n=367), rearing of non-Friesians and non-Friesian crosses(87.5%; n=367), and registering increasing trend in income from milk sales (68.4%; n=367) as measures for local adaptation to climate change effects. The strategies adopted are consistent with those reported by FAO, (2011) and LVOS, (2013). The strategies identified were all around farming systems, production systems, breed choices, feeding strategies, herd sizes and labour demand. The final strategy (recording an increasing trend in income from dairying) is more of the result of the combination of the adaptive practices adopted by smallholder dairy farmers and is a measure of the sustainability of the gains. From the findings, the practice of mixed farming, non-intensive dairy production system, establishment of own fodder, rearing of crossbred cattle, and which are well adapted (non-Friesians and their crosses) to local conditions seemed to make highest contributions to climate change adaptability by the study respondents of South-western Kenya.

It is worth noting that almost all the adaptive strategies adopted by smallholder dairy farmers of the study site are soft, reactive and anticipatory adaptive strategies that are sometimes also referred to as *ex ante* and *ex post* adaptive measures(Bebe, 2003; Limantol *et al*., 2016; FAO, 2020)and took the form of modifications of the systems of production and management of the dairy enterprise (Tedesse & Dereje, 2018).Practicing mixed crop and dairy farming (96.5% of study respondents) has several advantages. First, it ensures efficient utilization of the available land for farming, whose size is continuously diminishing due to increasing population and land sub-division (Masere, 2015; Rojas-Downing *et al*., 2017). Secondly, the practice acts as a cushion against total loss in case of adverse weather conditions, for if one enterprise is affected, the farmer would still get some returns from the other as an alternative source of livelihood (Bagamba *et al*., 2012). Thirdly, the two enterprises, complement each other (Fadina & Barjolle, 2018), thereby reducing production costs and producing more food on less land (Rojas-Downing *et al*., 2017). Manure from the dairy enterprise would be used as fertilizer in the crop fields, while some products from the crop fields, such as sweet potato vines, maize stover, and banana stems, could be used ad dairy cattle feeds (Bagamba *et al*., 2012; Ngare, 2017). Moreover, some fodder crops, such as desmodium are nitrogen-fixing, and would, thus, help to further enrich the soil, thereby increasing the productivity of crops grown in the field (Fadina & Barjolle, 2018).

Findings of Principal Component Analysis (PCA) indicated (Table 6) that mixed crop and livestock farming, non-intensive production system(i.e. mixture of stall feeding in zero grazing units and tethering or free grazing) and establishment of own fodder for the dairy enterprise were the three factors that strongly influenced climate change adaptability by the smallholder dairy farmers; followed closely by adoption of non-pure breeds of dairy cattle (i.e. cross breeds) and rearing of breeds that are perceived to be highly adaptable to the local conditions and in the context of changing climatic conditions (i.e. Non Friesians and their crosses, as Friesians are perceived to be highly vulnerable to climatic variability). These findings further re-enforce the fact that the smallholder dairy farmers of the study area perceive that changes have taken place in the climate of the study area, have effects on dairy enterprise and need to be addressed (Fadina & Barjolle, 2018; Tedesse & Dereje, 2018) hence; are taking measures to do so. The choice of adaptation measures are consistent with those that are being practiced by other farmers in Sub-Saharan Africa (Bagamba et al., 2012; Kirui *et al*., 2015; Rojas-Downing *et al*., 2017).

Further, findings of PCA (Table 7) that smallholder dairy farmers who chose to go for non-intensive dairying were about 39% more likely to adopt mixed farming, and about 57% more likely to establish own fodder on-farm. Those that opted for mixed farming were about 65% more likely to practice non-intensive dairying; about 78% more likely to keep cross breeds of dairy cattle, and about 80% more likely to rear non-Friesian breeds and their crosses that are considered more adaptable to the climatic conditions of the study area. On the other hand, the smallholder dairy farmers who had established own fodder on-farm were about 88% more likely to reduce their herd sizes to about 2 dairy cattle.

Table 7 further indicates that in terms of uniqueness, 66.8% of the variance in farming type is not shared with other variables in the overall factor model. On the contrary, the number of dairy cattle kept has low variance not accounted for by other variables, being 20.41%. This implies that the number of dairy cattle kept is a strong predictor of adaptability of smallholder dairy farmers in the study area.

Correlation coefficients for rotated factor loadings are presented in Table 8. The three factors (Mixed Farming, Non-intensive production system, and Own Fodder) combined account for 52.78% of the total variance observed, indicating that the practice of mixed crop and livestock farming, non-intensive production dairy rearing system and establishment of own fodder were the three greatest predictors of smallholder dairy farmers' adaption to climate change within the study area. From Table 8, it is further observed that Mixed Farming (Factor 1) could predict smallholder dairy farmers' choice of farming type to be adopted by 49.6%; dairy production system to practice by about 69.5%; breed of dairy cattle to keep by about 71.4%; and consideration of the adaptability of the breed to the local environment by about 79.1%. On the other hand, Non-intensive production system (Factor 2) could predict smallholder dairy farmers' consideration of the source of fodder for the dairy herd by about 62.7%; and the trend in income from sale of milk form then dairy herd by about 67%. Own fodder (Factor 3) was the greatest predictor of smallholder dairy farmers' choice of number of dairy cattle kept by about 88.2%. It could also predict the respondents' consideration of the main source of farm labour (whether household or non-household) by about 37.6%. Thus, farming type has a close relationship with dairy production system, breed choices, and a consideration of adaptability of the breeds to local conditions; while fodder availability has a close relationship with number of dairy cattle kept and source of farm labour to take care of the cattle.

4.2.2.4 Significance of the adaptive strategies to climate change

Mixed crop and livestock farming with an Eigen value of 1.934 (Table 6) could be attributed to an attempt by the study respondents to adapt to feed shortages as reported by Moran (2005), and to maximize on land productivity and gain complementarity of the crop and livestock enterprises (Bagamba *et al*., 2012; Kirui *et al*., 2015; Tedesse & Dereje, 2018), thereby enhancing returns on investments (Rojas-Downing *et al*., 2017). In this way, the crops and crop residues could supplement dairy animal feeds, even as the manure from the dairy farm is used to improve soil fertility, hence; crop productivity(Fadina & Barjolle, 2018). These findings are consistent with several findings of similar studies done across Sub-Saharan Africa (Hassan & Nhemachena, 2008; Ngare, 2017; Odari, 2018). However, Wamalwa (2015) established that most smallholder farmers adapted to climate change by diversifying out of agriculture. Mixed crop and livestock farming could also be attributed to an attempt by the study respondents to spread out risks of total loss from production, ensure sustainability in business, complementarity of enterprises (crop and livestock), increases in household income; and reduction in the overall production cost, as was argued out by Somda *et al.* (2004).

Non-intensive dairying with an Eigen Value of 1.272 (Table 6) is practiced by study respondents in order to efficiently utilize scarce feed resources, give the farmer flexibility to engage in other activities, reduce labour demand and cost of animal health management on the farm. This is consistent with findings by Ketema & Tsehay (1992) regarding climate-smart approaches to smallholder dairy development in Ethiopia.

Keeping of non-pure breeds had an Eigen Value of 0.921 (Table 6). The study respondents adopted this strategy mainly to adapt to parasites and diseases. Besides adaptability to disease and parasite challenges, crossbred cattle can withstand feed, water and thermal stress better than purebred cattle (Quddus, 2012). The study respondents generally rear Ayrshires and Guernseys and their crosses (Eigen Value of 0.896 as shown in Table 6) for their tolerance to the high temperatures and diseases and parasites, as opposed to Friesians that used to be very common in the early days. This finding is consistent with findings by Kirui (2014).

Study respondents also established own fodder (Eigen Value of 1.017 as shown in Table 6 in order to ensure sustainable feed availability to the dairy cattle, and the acreage of own feed was used to determine the number of dairy cattle kept. Other than depending on traditional fodder crop (Napier grass), focus group discussants indicated they diversified feed sources (including Boma Rhodes grass, desmodium, sweet potato vines, Bracheria, chopped maize stover treated with molasses and other improved Napier grass cultivars) and practiced more dry feeding rather than wet feeding. Other than limited land sizes, low income base, ignorance, poor extension contact, and long distances to nearest feed stockists were some of the factors that focus group discussants indicated limited them from having sustainable access to high quality cattle feeds. This has the effect of compromising the breeding of the dairy cattle, thereby elongating the calving interval. These findings are consistent with those of Howden *et al*., (2007). Maleko *et al*. (2018) also found that own-fodder provide the main feed source (73%) for smallholder dairy farmers of Western Usamabra Highlands in Tanzania; and by Moran (2005) that feed shortages remains a major constraint in smallholder dairy farming, with feed costs making for 50%-60% of total cost of milk production.

The focus group discussants indicated that labour demand has tended to increase over time as they endeavoured to adapt to climate change effects. This finding was corroborated by Morton (2007); Hassan & Nhemachena (2008); and Wamalwa (2015), suggesting that availability of labour may strongly determine diversification of farming from monoculture to mixed cropping and mixed crop and livestock farming systems. To cope with the labour shortages, focus group discussants indicated that they relied more on household labour, reduced the herd size to 2 dairy cattle, and hired extra labour at peak periods. Use of family labour to mitigate labour shortage was also established by Hassan & Nhemachena (2008); Wamalwa (2015), and Amuge & Osewe (2017); with a significant relationship being established between large family sizes and smallholder farmers divesting from monoculture into mixed crop and dairy farming systems as an adaptive strategy to climate change (Hassan and Nhemachena, 2008). Reduction of herd size to 2 dairy cattle was also established by

Kirui (2014). These findings, however, contradict those by Kasulo *et al.* (2012) and Tripathi & Mishra (2017) who concluded that dairy farmers either did not perceive climate change as an immediate problem, or did, but took only implicit measures to adapt to climate change.

Figure 5 indicated that majority (68.4%) of the study respondents had experienced an increase in income from milk sales over the past ten (10) years. This finding corroborates that of Shikuku *et al.* (2017) that prioritized climate-smart livestock technologies in rural Tanzania. Shikuku *et al.* (2017) indicated that both households with local cows and those with improved cows had increased income and food security.

4.2.2.5 Level of adoption of climate change adaptive strategies

The Z-score analyses indicate that Migori smallholder dairy farmers are generally highly adapted to climate change effects; indicative of the fact that they are high adopters of adaptive strategies to climate change effects. This is consistent with several study findings on climate change adaptation (Safdar *et al*., 2014; Rojas-Downing et al, 2017; Fadina & Barjolle, 2018), but contradicts findings by Amuge & Osewe (2017) regarding the level of feed based technologies among smallholder dairy farmers of Ekerenyo Sub-county, and by Olumba & Rahji (2014) concerning adoption of improved plantain technologies in Anambra State, Nigeria. This finding highlights the serious impact that climate change has on smallholder dairying, such that whereas adoption level for most dairy technologies by smallholder dairy farmers tend to be low, that of climate change adaptation technologies is generally high among smallholder farmers who perceive that climate change has taken place in their area.

4.3 Influence of Socio-demographic characteristics on smallholder dairy farmers' climate change adaptation[2]

4.3.1 Results

4.3.1.1 Socio-demographic profile of study respondents

62.7% of the study respondents were males, while 37.3% were females. Marital status and education profile of the study respondents are presented in Figures8 and 9, respectively. Figure 8 shows that majority (89.4%) of the study respondents were married, 9.0% were widows, 0.8% were widowers; while 0.3% were separated. Only 0.5% of the study respondents were single.

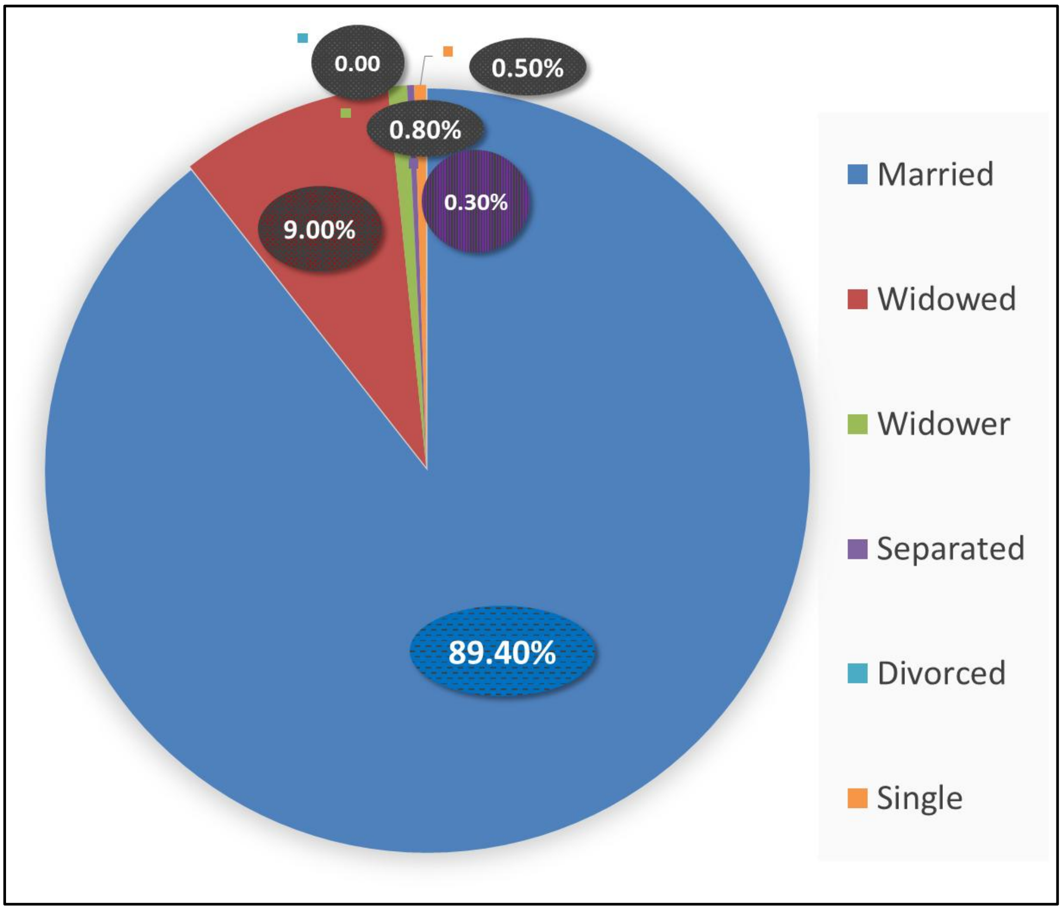

Figure 8: Distribution of respondents by marital status (n=367)

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[2]Findings of this objective have been published in *Journal of Atmospheric and Climate Sciences*, Vol. 9, No. 4, pp. 583-599 (October, 2019). http://www.scirp.org/journals/acs. ISSN Online: 2160-0422; ISSN Print: 2160-0414.

As shown in Figure 9, the proportion of respondents that completed Primary School was the same as that which completed Secondary Education, being 21.3% each. 12.3% of the respondents went to Secondary School, but did not complete Secondary Education. Some 3% of the respondents had attained first degree, with 10.4% having attained Certificate Level of Education.

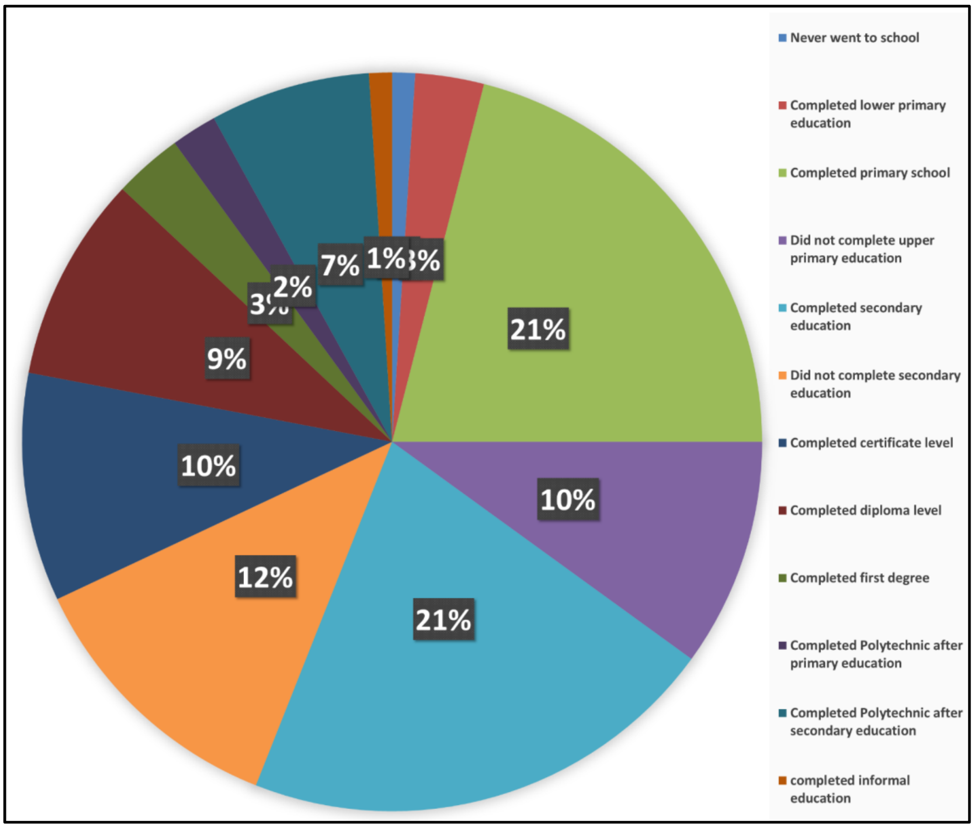

Figure 9: Distribution of respondents by highest level of education (n=367)

The mean, range and standard deviation of age of respondents, household size, and experience in dairying are presented in Table 11. The mean age of the respondents was 50.69 years; mean household size was 6.23; while the mean level of experience in dairying was 15.66 years.

Table 11: Summary of selected Socio-demographic measures (n=367)

Socio-demographic parameter	Mean Value	Range		SD
		Min. Value	Max. Value	
Age of study respondents (years)	50.69	20	85	11.86
Household size (persons)	6.23	1	15	2.52
Level of experience in dairy farming (years)	15.66	10	38	5.60

4.3.1.2 Influence of Smallholder dairy farmers' Socio-demographics on their adaptation to climate change effects

Table 12 presents a summary of the findings of socio-demographic characteristics with significant relationships on climate change adaption, when the relationship with the characteristics were considered individually. Table 12 shows that male smallholder dairy farmers had a 63% likelihood of experiencing an increasing trend in income from milk sales (Crude Odds =0.63; p=0.04). The Table also shows that smallholder dairy farmers with large household sizes were about 69% more likely to establish their own fodder (Crude Odds=0.69; p=0.00) and 85% more likely to experience an increasing trend in income from milk sales (Crude Odds =0.85; p=n/a) compared to those with smaller household sizes. Moreover, older farmers were 97% more likely to rear adaptable non-Friesian breeds of dairy cattle and their crosses (Crude Odds=0.97; p=0.02) and about 96% more likely to establish own fodder for their dairy cattle (Crude Odds=0.96; p=0.03) that the younger ones.

Table 12: Relationship between individual Socio-demographic factors and selected climate change adaptive strategies

Adaptive strategies	Crude Odds (95% C.I) for Gender (Male)			Crude Odds (95% C.I.) for Age			Crude Odds (95% C.I) for Household size		
	Odds	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**
Breeds kept	1.42	0.73-2.77	0.30	**0.97**	**0.94-1.00**	**0.02**	0.96	0.85-1.08	0.52
Own fodder	1.50	0.69-3.26	0.30	**0.96**	**0.93-1.00**	**0.03**	**0.69**	**0.56-0.85**	**0.00**
Dairy income trend	**0.63**	**0.40-0.99**	**0.04**	1.02	1.00-1.04	0.02	**0.85**	**0.78-0.93**	**n/a**

Table 13 presents findings of the relationships when smallholder dairy farmers' socio-demographic characteristics were jointly considered. Gender significantly influenced the adoption of household members as main source of farm labour for the dairy enterprise, such that male smallholder dairy farmers were about 32% more likely to use members of the household as the main source of farm labour (Adjusted Odds=0.32; p=0.05) compared to their female counterparts; while household size significantly influenced the establishment of own fodder and experiencing an increasing trend in income from milk sales, such that farmers with large household sizes were about 70% more likely to establish own fodder (Adjusted Odds=0.70; p=0.00) and 82% more likely to experience an increasing trend in income from milk sales (Adjusted Odds=0.82; p=n/a)

Table 13: Relationship between Socio-demographic factors and selected climate change adaptive strategies

Adaptive strategies	Adjusted Odds (95% C.I.) for Gender (Male)			Adjusted Odds (95% C.I.) for Household Size		
	Odds	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**
Own fodder	1.20	0.45-3.22	0.72	**0.70**	**0.55-0.88**	**0.00**
Farm labour source	**0.32**	**0.10-1.00**	**0.05**	1.17	0.92-1.49	0.19
Dairy income trend	1.23	0.68-2.23	0.49	**0.82**	**0.73-0.91**	**n/a**

Table 14 presents the relationships between smallholder dairy farmers' years of experience in dairying and climate change adaptive strategies employed. The Table indicates that years of experience has no statistically significance relationship with any of the climate change adaptive strategies employed by smallholder dairy farmers (Adjusted Odds for mixed farming=0.96; p=0.49; Adjusted Odds for Non-intensive production system=0.99; p=0.78; Adjusted Odds for Own Fodder=0.98; p=0.67; Adjusted Odds for cross bred cattle=1.02; p=0.56; Adjusted Odds for Adapted breeds kept=0.98; p=0.55; Adjusted Odds for Number of dairy cattle kept=1.11; p=0.08; Adjusted Odds for household labour=0.98; p=0.65; and Adjusted Odds for increasing trend in dairy income=1.01; p=0.82).

Table 14: Relationship between Dairy experience and climate change adaptation

Adaptive strategies	**Crude Odds (95% C.I.) for Dairy Experience**			**Adjusted Odds (95% C.I.) for Dairy Experience**		
	Odds	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**
Farming type	0.98	0.90-1.08	0.71	0.96	0.84-1.08	0.49
Production system	0.96	0.90-1.04	0.34	0.99	0.89-1.09	0.78
Own Fodder	0.92	0.84-1.01	0.09	0.98	0.87-1.09	0.67
Breed types	1.03	0.97-1.10	0.33	1.02	0.95-1.10	0.56
Breeds kept	0.96	0.91-1.00	0.07	0.98	0.92-1.04	0.55
Number of dairy cattle kept	1.10	1.00-1.22	0.06	1.11	0.99-1.24	0.08
Household labour	0.99	0.92-1.07	0.75	0.98	0.88-1.08	0.65
Dairy income trend	1.02	0.98-1.06	0.42	1.01	0.96-1.06	0.82

Table 15 shows the relationship between marital status and climate change adaptive strategies, when marital status is considered individually. From the Table, there is no statistically significant relationship between marital status and climate change adaptation

(None of the Crude Odds and Confidence Interval [C.I] fall between 0 and 1, and with a p-value <0.05).

Table 15: Single relationships between Marital status and climate change adaptation

Adaptive strategies	Crude Odds (95% C.I.) for Marital Status											
	Married			Separated			Widow			Widower		
	Odds	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**
Farming type	n/a	n/a	n/a	1.00	n/a	n/a	n/a	n/a	n/a	1.00	n/a	n/a
Production system	22.43	1.33-377.43	0.03	Ref.	n/a	1.00	15.50	0.68-350.64	0.08	2.00	0.05-78.25	0.71
Own Fodder	Ref.	n/a	1.00	1.00	n/a	1.00	Ref.	n/a	1.00	1.00	n/a	1.00
Breed types	n/a	n/a	1.00	1.00	n/a	1.00	n/a	n/a	1.00	n/a	n/a	1.00
Breeds kept	n/a	n/a	1.00	1.00	n/a	1.00	n/a	n/a	1.00	n/a	n/a	1.00
No. of dairy cattle	n/a	n/a	1.00	1.00	n/a	1.00	n/a	n/a	1.00	1.00	n/a	1.00
HH labour	n/a	n/a	1.00	1.00	n/a	1.00	n/a	n/a	1.00	1.00	n/a	1.00
Dairy income trend	n/a	n/a	1.00	1.00	n/a	1.00	n/a	n/a	1.00	n/a	n/a	1.00

Table 16 presents a summary of the relationship between marital status and climate change adaptive strategies, when marital status is jointly considered with other socio-demographic characteristics of smallholder dairy farmers (p<0.05). From the Table, there is no statistically significant relationship between marital status and climate change adaptation (None of the Adjusted Odds and Confidence Interval [C.I] fall between 0 and 1, and with a p-value <0.05).

Table 16: Joint relationships between Marital status and climate change adaptation

Adaptive strategies	Adjusted Odds (95% C.I.) for Marital Status											
	Married			Separated			Widow			Widower		
	Odds	C.I	P-value	Odds	C.I	P-value	Odds	C.I	P-value	Odds	C.I	P-value
Farming type	n/a	n/a	1.00	2.83	n/a	1.00	n/a	n/a	1.00	1.25	n/a	1.00
Production system	2.42	0.02-242.86	0.71	Ref.	n/a	1.00	3.51	0.03-380.52	0.60	0.32	0.00-73.02	0.68
Own Fodder	Ref.	n/a	1.00	0.32	n/a	1.00	Ref.	n/a	1.00	11.67	n/a	1.00
Breed types	n/a	n/a	1.00	0.69	n/a	1.00	n/a	n/a	1.00	n/a	n/a	1.00
Breeds kept	n/a	n/a	1.00	1.00	n/a	1.00	n/a	n/a	1.00	n/a	n/a	1.00
No. of dairy cattle	n/a	n/a	1.00	7.00	n/a	1.00	n/a	n/a	1.00	4.67	n/a	1.00
HH labour	n/a	n/a	1.00	13.72	n/a	1.00	n/a	n/a	1.00	1.70	n/a	1.00
Dairy income trend	n/a	n/a	1.00	1.46	n/a	1.00	n/a	n/a	1.00	n/a	n/a	1.00

Table 17 presents a summary of the joint relationships between Educational level and farming type, production system, own fodder, and breed types adaptive strategies. The Table shows that there is no statistically significant relationship between educational level, farming type, production system, source of fodder, and breed type adaptive strategies (None of the Adjusted Odds and Confidence Interval [C.I] fall between 0 and 1, and with a p-value <0.05).

Table 17: Joint relationships between Educational level and selected climate change adaptive strategies

Highest Educational level	**Adjusted Odds (95% C.I.) for Climate Change Adaptive Strategy**											
	Farming type			**Production system**			**Own Fodder**			**Breed types**		
	Odds	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**
Completed Lower Pri.	0.45	n/a	1.00	28.13	0.56-1406.02	0.10	4.65	n/a	1.00	5.88	0.14-239.12	0.35
Didn't complete Upper Pri.	n/a	n/a	1.00	25.88	0.77-864.66	0.07	Ref.	n/a	1.00	4.47	0.18-112.67	0.36
Completed Pri.	n/a	n/a	1.00	148.56	3.34-6598.48	0.01	Ref.	n/a	1.00	4.77	0.22-105.89	0.32
Didn't complete Sec.	n/a	n/a	1.00	24.44	0.72-831.76	0.08	Ref.	n/a	1.00	2.73	0.11-68.16	0.54
Completed Sec.	n/a	n/a	1.00	36.19	1.10-1187.75	0.04	Ref.	n/a	1.00	3.64	0.16-85.26	0.42
Comp. Polytech. After Pri.	0.10	n/a	1.00	Ref.	n/a	1.00	Ref.	n/a	1.00	0.83	0.02-28.72	0.92
Completed Polytech after Sec.	0.18	n/a	1.00	49.15	0.96-2529.16	0.05	Ref.	n/a	1.00	5.25	0.17-162.10	0.34
Completed Adult Educ.	0.09	n/a	1.00	Ref.	n/a	1.00	20.29	n/a	1.00	Ref.	n/a	1.00
Completed Cert.	n/a	n/a	1.00	26.32	0.74-931.41	0.07	5.37	n/a	1.00	3.93	0.15-101.82	0.41
Completed Diploma	0.20	n/a	1.00	64.36	1.23-3369.29	0.04	Ref.	n/a	1.00	1.46	0.06-36.17	0.82
Completed Degree	0.18	n/a	1.00	Ref.	n/a	1.00	Ref.	n/a	1.00	1.24	0.04-36.79	0.90

Table 18 presents a summary of relationships between educational level, breeds kept, number of dairy cattle kept, major source of farm labour, and dairy income trend ($p<0.05$). The Table shows that there is no statistically significant relationship between educational level, breeds kept, number of dairy cattle kept, main source of farm labour, and dairy income trend (None of the Adjusted Odds and Confidence Interval [C.I] fall between 0 and 1, and with a p-value <0.05).

Table 18: Joint relationships between Educational level and selected climate change adaptive strategies

Highest Educational level	Adjusted Odds (95% C.I.) for Climate Change Adaptive Strategy											
	Breeds kept			No. of dairy cattle kept			Source of farm labour			Dairy income trend		
	Odds	C.I	P-value	Odds	C.I	P-value	Odds	C.I	P-value	Odds	C.I	P-value
Completed Lower Pri.	5.32	0.20-144.89	0.32	n/a	n/a	1.00	1.98	n/a	1.00	0.48	0.02-11.23	0.65
Didn't complete Upper Pri.	2.39	0.11-50.82	0.58	n/a	n/a	1.00	n/a	n/a	1.00	0.66	0.03-13.17	0.79
Completed Pri.	5.04	0.25-100.78	0.29	n/a	n/a	1.00	1.21	n/a	1.00	0.76	0.04-14.33	0.86
Didn't complete Sec.	2.48	0.11-54.03	0.56	n/a	n/a	1.00	n/a	n/a	1.00	1.76	0.09-35.61	0.71
Completed Sec.	4.58	0.21-98.86	0.33	n/a	n/a	1.00	n/a	n/a	1.00	2.17	0.11-42.45	0.61
Comp. Polytech. After Pri.	Ref.	n/a	1.00	1.54	n/a	1.00	0.67	n/a	1.00	4.38	0.12-165.46	0.43
Completed Polytech after Sec.	Ref.	n/a	1.00	n/a	n/a	1.00	n/a	n/a	1.00	1.23	0.06-26.58	0.89
Completed Adult Educ.	Ref.	n/a	1.00	0.88	n/a	1.00	n/a	n/a	1.00	Ref.	n/a	1.00
Completed Cert.	3.18	0.14-71.60	0.47	n/a	n/a	1.00	n/a	n/a	1.00	2.02	0.10-41.88	0.65
Completed Diploma	2.48	0.11-57.72	0.57	n/a	n/a	1.00	n/a	n/a	1.00	5.14	0.22-122.54	0.31
Completed Degree	1.34	0.05-35.95	0.86	2.70	n/a	1.00	n/a	n/a	1.00	1.08	0.04-27.48	0.97

4.3.2 Discussions

4.3.2.1 Gender

Ihemenzie *et al.* (2018) noted that socio-economic status is an important factor that affects the respondents' behaviour and attitude towards climate change adaptation. Being male or female, and the social roles that the society ascribe to that may bring a difference in perceptions and choices of technologies to adapt to climate change effects (Okuthe*et al*., 2007; Akhter & Olaf, 2016; and Zamasiya*et al*., 2017). Males may tend to choose some sets of adaptive strategies compared to females, and vice-versa. Moreover, several studies have shown that there is gender disproportionality in terms of access to and control over resources, as well as decision making at the household, farm, and community levels (Midgley & Antzoylatos, 2012; Pooja & Rekha, 2017; Amuge & Osewe, 2017).

The study indicated (Table 12) that male smallholder dairy farmers had a 63% likelihood of experiencing an increasing trend in income from milk sales (Crude Odds =0.63; p=0.04) and that (Table 13) male smallholder dairy farmers were about 32% more likely to use members of the household as the main source of farm labour (Adjusted Odds=0.32; p=0.05) compared to their female counterparts.

These differences could be explained on the basis of several factors. First, it is worth noting that the study setting was that of a patriarchal society, where males tend to dominate in control over resources and decision-making (Midgley & Antzoylatos, 2012). Mutunga et al. (2017) argued thatmale household heads are often more likelyto get information on climate change and new technologies, and to take risky business decisions compared to female-headed households. Thus, they could quickly take up investments in climate change adaptation technologies compared to female-headed ones.

Secondly, males and females have different values and world views, such that whereas women tended to be more considerate, males are generally more aggressive and open to trying out new ideas (Hitayezu*et al*., 2017). In this study being male significantly influenced the study farmers to experience an increasing trend in income from milk sales (Crude

Odds=0.63; p=0.04) and to use household members as the main source of farm labour (Adjusted Odds=0.32; p=0.05). This could be due to the fact that as the head of the household, the males made the decisions regarding chores to be undertaken by members of the household, and so, in an effort to reduce on production costs and maximize on returns, enlisted the service of household members in providing labour in the dairy enterprise in an effort to cope with climate change effects (Smit & Pilisofova, 2018).This finding is consistent with other findings on influence on gender on technology adoption and climate change adaptation (Atibioke *et al*., 2012; Hitayezu & Ortmann, 2017; Masud *et al*., 2017; Mwalukasa *et al*., 2018), but differs with other study findings on the same (Gonza’lez-Herna’ndez, *et al*., 2019). The differences in terms of influence of gender on climate change adaptation largely accrue from the fact that women, men and children experience climate change impacts differently, depending on where they live, how they sustain their livelihoods, and the roles they play in their families and communities (Daze, 2019). The insignificant influence of gender in joint analysis of socio-demographic factors in Table 13 indicates that many factors, other than gender influence smallholder farmers’ ultimate choice of adaptive strategies to climate change (Limo, 2013; Odhiambo, 2014; and Amuge & Osewe, 2017).

4.3.2.2 Age

As already seen from literature, with age comes the much-needed experience to handle stressful situations and adapt to climate change effects in smallholder dairying (Ndiema, 2002; Zamasiya *et al*., 2017; Ihemezie *et al*., 2018).The expectation, therefore, would be that older farmers would be better adapted to climate change effects. From the study findings, when age was individually considered, older farmers had about 97% likelihood of adopting adaptable Non Friesian breeds and their crosses (Crude Odds=0.97; p=0.02) and about 96% likelihood of establishing own fodder (Crude Odds=0.96; p=0.03) as shown in Table 12, consistent with findings by Tiyumtaba (2016) on the adoption of feed-based, breed-based, and health-based climate change adaptation strategies; Amuge & Osewe (2017) on the influence of age on the adoption of feed-based dairy technologies; Pooja & Rekha (2017) on the adoption of mobile technology by farmers in their farm operations; and by Mwalukasa *et al*. (2018) on the use of mobile phones to access information on climate change adaptation. Nevertheless, this finding differs with that of Muzamhindo *et al*. (2015) that age of household head negatively influenced climate change adaptation decisions.

When all socio-demographic factors were jointly considered, the study established that age had no statistically significant influence on climate change adaption (Table 13), and instead; only gender of the household head and the household size did.This finding is consistent with findings by Limo (2013) that age had no statistically significant relationship with adaptation of tea farmers to climate change, and by Ihemezie *et al*. (2018) that most elderly people in Leeds-United Kingdom, did not consider heat wave as a serious climate risk that requires adaptation. The explanation for this was given by Hassan & Nhemachena (2008) that there is mixed influence of age on the skills that farmers employ to adapt to climate change, and to adopt new technologies. Thus, some skills are quickly picked up by younger generation farmers (especially if they resonate with modern technologies), while others are easily picked by older generation farmers (especially if they require bringing to memory that which has been learned over time).

4.3.2.3 Marital status

Generally, marriage is expected to bring with it a sharing of experiences and resources, that would make household heads adapt better to climate change (Midgley & Antzoylatos, 2012; Muthui, 2015; Akhter & Olaf, 2016). In this study, however, when socio-demographic factors were considered individually (Table 15), marital status had no statistically significant influence on climate change technology adoption, same to when the factors were jointly considered (Table16). This finding is consistent with that of Pooja & Rekha (2017) that marital status had no statistically significant influence on the adoption of mobile phone technology by farmers in their farm operations; and byAmuge & Osewe (2017) that marital status did not seem to have an influence on the adoption of improved feed-based dairy technologies. but differs from findings by Mwalukasa *et al.* (2018); who found marital status to positively and significantly influence the use of mobile phones by farmers in accessing rice information on climate change adaptation. The possible explanation for the finding in this study is that with marriage, decision-making could be slow as extensive consultations are needed before a final decision is made. On the contrary, household heads that are single, separated, divorced, or widowed would have to make minimal consultations before arriving at the final decision to adopt a climate change adaptation practice (Mudombi-Rusinamhodzi *et al.*, 2012).

4.3.2.4 Education Level

Educated farmers are expected to be better adopters of agricultural technology, since education gives more information and knowledge on particular issues, exposes people to reason better and understand issues better, hence; make better decisions (Abayomi, 2013; Fadina & Barjolle, 2018). Nevertheless, in this study respondents' educational level did not have any statistically significant influence on strategies employed by smallholder dairy farmers to adapt to climate change effects as shown by Tables 17 & 18 (None of the variables has $0<$Adjusted Odds <1; $0<$C.I.<1; $p<0.05$). This finding is consistent with findings byWamsler (2011) that formal education does not play a significantly determinant role for men with regard to their adaptive capacity to climate change effects. Nevertheless, this finding differs from findings by Mutunga *et al.* (2017); Simotwo *et al*. (2018) and Fadina & Barjolle (2018) that education positively and significantly influenced farmers' decisions to adapt to climate change variability, implying that education plays an important role in helping smallholder farmers to gain literacy that would enable them to search for information and make choices based on their preferences and level of information gathered(Tegegne, 2017).The findings also differ with that of Atibioke *et al*. (2012) that education positively and significantly influenced the adoption of grain storagetechnologies.

The most probable explanation for the lack of statistically significance influence by household heads' educational level on climate change adaptation by smallholder farmers of the study area; first, could be that the study respondents had already acquired a lot of free information and sensitization on climate change and adaptation from varies sources, which enabled them to make sound decisions on whether and how to adapt, irrespective of their educational level (Simotwo *et al*., 2018). Secondly, with climate change adaptation, farmers' perceptions of the climatic changes taking place in their place (see section 4.3) play a more significant role than education level of the household head (Ihemezie *et al*., 2018).

4.3.2.5 Household size

Studies show that in subsistence and resource-poor households, especially in developing countries, large households sizes (in real terms) would have no statistically significant influence on climate change adaptation, as the large number of members of the household does not contribute to a large pool of financial resource for improved climate change adaptation (Mudombi-Rusinamhodzi *et al*., 2012). Nevertheless, in farming communities, and where practices require labour investments, it has been observed that generally; farmers with larger household sizes tend to adopt more labour intensive agricultural technologies compared to their counterparts with smaller family sizes (Hassan & Nhemachena, 2008). In this study, when considered individually (Table 12), household size positively and significantly influenced the establishment of own fodder (Crude Odds=0.69; p=0.00) and realization of an increasing income trend from milk sales (Crude Odds=0.85; p=n/a). This was influence was also positive and significant when household size was considered alongside the other socio-demographic factors (Table 13), influencing establishment of own fodder by a factor of 0.70 (Adjusted Odds=0.70; p=0.00) and experiencing of an increasing trend in earning from milk sales (adjusted Odds=0.82; p=n/a). These findings are consistent with findings by Gbetibou (2009); Abayomi, 2013; Muzamhindo*et al*., 2015; Amuge & Osewe, 2017, but differ from those by Mudombi-Rusinamhodzi *et al*., 2012; Fadina & Barjolle, 2018). Mudombi-Rusinamhodzi *et al.* (2012) argued that the size of the household in their study did not matter as all important decisions regarding the household were made by the household head. In this study, dairy enterprise being a labour-intensive undertaking (Bebe, 2013), smallholder dairy farmers with large family sizes were about 70% more likely to establish own fodder, as the family provided the much-needed labour for the undertaking. The significant role played by household size in climate change adaptation by smallholder farmers is well demonstrated by Akhter & Olaf (2016), who found the number of adaptive strategies being practiced to be positively associated with household size, among others.

4.3.2.6 Experience in dairy farming

Experience in dairy farming could be as a result of years taken in smallholder dairying, knowledge acquired (formally and informally) over the period, and learning from historical challenges (Ogindo, 2020, personal communication). Years of experience the household heads have in smallholder dairying is expected to give them more competence in weather forecasting that would increase their likelihood of practicing different climate change adaptation practices (Tiyumtaba,2016; Hitayezu & Ortmann, 2017;Fadina & Barjolle, 2018). In this study, the smallholder dairy farmers' experience in dairying had no significant influence on the adoption of climate change adaptation strategies (Table 14). Although this contradicts findings from several studies (Gbetibou, 2009; Limo, 2013; Mutunga *et al*., 2017; Hitayezu & Ortmann, 2017; Mwalukasa *et al*., 2018), it confirms other study findings (Simotwo *et al*., 2018; Marie *et al.,* 2020). The findings of this study could be explained by the fact that all the study respondents had been stratified by virtue of having an experience of at least 10 years in dairy farming, and that all the study respondents had a lot of free access to information regarding climate change and climate change adaption from the many sources and got support from many institutions as was established from qualitative study.

4.4Climate change perceptions and smallholder dairy farmers' adaptation

4.4.1 Results

4.4.1.1 Respondents' perceptions of climate changes in the study site

The proportions of respondents and their perceptions of climate change effects is presented in Table 5(Section 4.1.1.3). The study established from discussion with elders (females and males aged 60 years and above) that in the 60's and 70's both day and night temperatures used to be colder than today. As from late 70's and early 80's there has been considerable decrease in tree cover in Migori County, leading to a remarkable increase in day and night temperatures, which has meant that during the day, people would rarely cover themselves with heavy jackets like before. Likewise, in the night, people would rarely cover themselves with heavy blankets, like *Raymond's*® that was popular in those days. The increase has been very steady and presenting a direct proportionality with time, more so since the year 2000. Migori County Director for Meteorological Services affirmed that temperatures have been steadily increasing with time, with a global increase of 0.3^{o}C being registered.

Engagements with focus group discussants, both elders and dairy farmer groups, indicated that the total amount of rainfall may have slightly increased, comparing the 60's and the years after 2000. What seems to have changed much are the distribution and the rainfall patterns. Rainfall in the '60s and up to the year 2000 used to have distinct seasons-long rains and short rains, with long rains coming from January to May; while short rains would be experienced between September and November. As from the year 2001, long rains are experienced between March and May, while short rains come between October and December, depicting a one month shift from the norm.

Long rains were generally higher in amounts compared to short rains, and would rain for 2-3 hours in the morning, and another 2-3 hours in the afternoon and/or the night; while short rains would generally come mainly in the afternoon. Nevertheless, as from the year 2001, onset of the rainy seasons is not very predictable, just like the duration and amounts. Sometimes, long rains delay and begin as late as May, and end in a month or so time; with the amount received in a period of three weeks being almost equal to what would in the early days (1960s-2000) be received in 3 months' time. Sometimes, as from the year 2001, the long rains would continue, with another season bridging between the long and short rainy seasons, such that rainfall would somehow be continuous throughout the year. A remarkable change is that sometimes more rain is received during the short rainy season than the long rainy season.

The study indicated that unlike in the days of 60's and 70's, rainfall distribution (temporal and spatial) is also very erratic since 2001, although the intensity has generally been increasing. Rainfall amounts vary from area to area, creating micro-climatic differences within the County and even within individual sub-counties, although an increasing trend has been noted. Table 19 presents a summary of the key perceptions (with respect to temperature and precipitation) of the elders, farmer groups and a dairy Cooperative Society, considering the period of 1960-2000 and the period of 2001-2017. Table 19indicates that generally both day and night temperatures have risen; while rainfall season have become less predictable, with the distribution being very poor.

Table 19: Summary of perceptions of climate changes by focus group discussants

Climatic parameter	**Climate period 1 (1960-2000)** **Key statement**	**Climate period 2 (2001-2017)** **Key statement**	**Category of discussant**
Day temp.	*"In the '60s and up to around the year 2000, day temperatures were lower than what it is in 2017".*	*Since 2001, day have increasingly become warmer than before, to the extent that one would think the sun has somehow come slightly down and closer to the Earth".*	Elders
Night temp.	*"Nights used to be very cold in the '60s up to around the year 2000".*	*"In 2017 and since 2001, nights have tended to be very hot. As a result, people no longer use such heavy blankets as **Raymond's ®.***	Rongo Dairy Farmers' Cooperative Society
Rainfall seasons	*"In the '60s and up to around the year 2000, seasons were very predictable. The long rains would come between March and May, while the short rains would come between August and October".*	*"The seasons have somehow become unpredictable since 2001, and are increasingly becoming so".*	Elders
Rainfall reliability	*"Long rains could easily be predicted, even from the direction of the winds and the clouds".*	*"As from the year 2001, and increasingly so over-time; rainfall is erratic and unpredictable".*	Cham Gi Wadu Dairy & Multipurpose Group
Rainfall intensity	*"Up to around the year 2000, rains would come in showers, but for a long time (called* ***kodh nyauru****)".*	*"In 2017 and since 2001, rains come for a short time, but of high intensity, violent and with thunder and lightning; and often very destructive winds".*	Rongo Dairy Farmers' Cooperative Society
Rainfall distribution	*"Rainfall used to be well distributed, both during the long and short rainy seasons".*	*"Rainfall has become erratic, and with an uneven temporal and spatial distribution".*	Rongo Dairy Farmers' Cooperative Society

Table 20 presents a summary of perceptions of climate changes taking place in the study area as reported by the key informants, considering the period of 1960-2000 and the period of 2001-2017. The Table shows that generally there has tended to be an increase in both temperatures (day and night) and rainfall amounts. While rainfall intensity has also increased, generally rainfall has tended to be less reliable, with no clear seasonality, while the distribution got worse.

Table 20: Summary of perceptions of climate changes by key informants

Climatic parameter	***Climate period 1 (1960-2000)***	***Climate period 2 (2001-2017)***	***Category of discussant***
	Key statement	***Key statement***	
Day temp.	*"Generally, day temperatures were lower compared to the period after 2001".*	*"Day temperatures have been hotter generally since 2001, but particularly much higher during the dry seasons".*	*Deputy Director-Livestock, Migori County*
Night temp.	*"Nights used to be very cold in the early days of 1960s and up to the year 2000".*	*"Night temperatures have generally become hotter since 2001; particularly during the dry seasons…"*	
Rainfall amounts	*"Other than such times as the heavy rainfall received all over Kenya around 1963 towards independence, Migori never used to receive much rainfall".*	*"Rainfall amounts have also increased since 2001".*	*Migori County Director for Environment*
Rainfall seasons	*"Farmers used to know of two rainy seasons-the long rains and short rains, and would plant appropriate crops for each season".*	*"Since 2001, seasonality of the rainfall is not so clearly demarcated"*	
Rainfall reliability	*"in the '60s and up to around 2000, rainfall used to be very predictable, making farmers realize good harvests".*	*"Since 2001, rainfall has become very unpredictable, with delays in the onset".*	
Rainfall intensity	*"In the '60s and up to around 2000, rainfall would come for a long time, but the intensity would be low compared to today".*	*"Since the year 2001, rainfall intensity has increased, with increased frequencies of hailstones".*	
Rainfall distribution	*"Generally, in the '60s and up to 2000, rainfall was well distributed".*	*"Rainfall distribution tends to have reduced and become poor over time, since 2001".*	*Migori County Commissioner for Cooperatives*
Rainfall duration	*"In the '60s and up to 2000, rainfall used to be well distributed, both over time and in geographical position across any given region"*	*"The spread of rainfall since 2001is very unpredictable".*	*Climate Change & Livestock production Expert-KALRO, Kisii*

4.4.1.2 Relationship between Smallholder Dairy Farmers' Perceptions of Climate Change Effects and Climate Change Adaptation

Table 21 presents a summary of the relationships between perception indicators for temperature and precipitation and farming type, own fodder, breed type, and breeds kept adaptive strategies among the study respondents. The table indicates that the perception that the study area had experienced a decrease in night temperature had a positive and statistically significant influence on the adoption of mixed farming method (Adjusted Odds=0.13; p=0.04). Similarly, the perception that the distribution of the short rains in the study area got worse positively and statistically significantly influenced farmers to establish their own fodder (Adjusted Odds=0.02; p=0.01). The perception that the study area had experienced no change in night temperatures had a slight positive, but statistically significant influence on farmers, making them rear Non-Friesian breeds and their crosses that are better adapted to the local conditions (Adjusted Odds=0.08; p=0.02). Similarly, the perception that night temperatures in the study area had decreased had a more positive and statistically significant influence on farmers' adoption of better adapted breeds (Odds=0.19; p=0.01).

Table 21: Relationships between climate change perceptions and Farming Type, Own Fodder, and Breed adaptability as Climate Change Adaptive strategies

Perception indicator	Adjusted Odds values for perception indicators in relation to climate change adaptation								
	Perceptions & Farming Type			Perceptions & Own Fodder			Perceptions & adaptability of breeds kept		
	Odds	C.I	P-value	Odds	C.I	P-value	Odds	C.I	P-value
Experienced a decrease in night temperatures*	**0.13**	**0.02-0.91**	**0.04**	0.60	0.03-10.89	0.73	**0.19**	**0.05-0.65**	**0.01**
Experienced no change in night temperatures*	Ref.	n/a	1.00	n/a	n/a	1.00	**0.08**	**0.01-0.64**	**0.02**
Distribution of short rains is worse*	n/a	n/a	1.00	**0.02**	**0.00-0.47**	**0.01**	n/a	n/a	1.00

Table 22 presents a summary of the relationships between respondents' perceptions on changes in temperature and precipitation and number of dairy cattle kept, main source of farm labour, and dairy income trend adaptive strategies. The Table indicates that farmers' decision to reduce dairy herd size to 2 was significantly influenced by their perceptions that rainfall seasons have remained the same (Adjusted Odds=0.02; p=0.00); rainfall seasons have reduced (Adjusted Odds=0.10; p=0.03); rainfall duration in a single rainy episode during the long rains has not changed (Adjusted Odds=0.01; p=0.03); and that the intensity of the long rains has increased (Adjusted Odds=0.01; p=0.01). Farmers who experienced an increasing trend in income from milk sales were significantly influenced by their perceptions that the area had not experienced a change in day temperatures (Adjusted Odds=0.05; p=0.02); that the area had experienced a decrease in day temperature (Adjusted Odds=0.02; p=0.02); and that the onset of the short rains is very unpredictable (Adjusted Odds-0.37; p=0.04).

Table 22: Relationships between climate change perceptions and Dairy cattle kept, Main source of labour and Dairy income trend as Climate Change adaptive strategies

Perception indicator	**Adjusted Odds values for perception indicators in relation to climate change adaptation**					
	Perceptions & No. of dairy cattle kept Adaptive Strategy			**Perceptions & trend in dairy income Adaptive Strategy**		
	Odds	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**
No change in day temperatures experienced*	Ref.	n/a	1.00	**0.05**	**0.00-0.60**	**0.02**
A decrease in day temperatures experienced*	Ref.	n/a	1.00	**0.02**	**0.00-0.62**	**0.02**
Rainfall seasons have remained the same*	**0.02**	**0.00-0.25**	**0.00**	n/a	n/a	n/a
Rainfall seasons have reduced*	**0.10**	**0.01-0.76**	**0.03**	n/a	n/a	n/a
Onset of short rains is very unpredictable*	0.82	0.13-5.15	0.83	**0.37**	**0.14-0.95**	**0.04**
Duration in a single rainy episode (Long rains) has not changed*	**0.01**	**0.00-0.64**	**0.03**	n/a	n/a	n/a
Intensity of long rains has increased*	**0.01**	**0.00-0.28**	**0.01**	n/a	n/a	n/a

4.4.2 Discussions

4.4.2.1 Farmers' perceptions of Climate Changes in Migori County-Kenya

Studies have shown that a farmer's climate change adaptation capacity depends on the farmer's perception climate change phenomenon, the need to provide solutions to it, and the opportunities at the farmer's disposal to enable him act appropriately (Tedesse & Dereje, 2018; Fadina & Barjolle, 2018). Scholars (Bagamba *et al*., 2012; Barnejee, 2015; Tedesse & Dereje, 2018) assert that for sound climate change adaptation policies, there is need for sound knowledge on farmers' perceptions of climate changes taking place in their areas; the extent to which this perception coincides with actual climatic data; potential adaptation measures; and factors influencing adoption of the potential strategies.

In this study, the respondents perceived that there has been an increase in both day and night temperatures, as well as in total amount of rainfall; whose seasonality and onset has become more unpredictable, the distribution and intensity more erratic, with short rains sometimes ending up being higher in amount and more reliable than the long rains. These perceptions are very close to the actual temperature and rainfall data gathered from the study site, and confirmed by Migori County Director of Meteorology. These findings are consistent with those of Gbetibou (2009). The perceived changes both in temperature and rainfall patterns have their direct and/or indirect influences on smallholder dairy farming. They also have a potential of determining the adaptive strategies that the smallholder dairy farmers would employ to cope with the effects of climate changes.

Study respondents perceived that there has been marked climatic changes experienced in the study area since the year 2000, resulting in increase in temperature and slight increases in total amount of rainfall received. Whereas climate change may have contributed to this, changes in farming patterns played a critical role, with introductions of sugarcane and tobacco plantations that meant cutting down of many trees to pave ways for the plantations. Interview with Migori County Director for Meteorological Services confirmed that temperatures have been steadily increasing with time, with a global increase of 0.3^{o}C being registered. These findings are consistent with climate change models for the Lake Victoria Region of East Africa that predict increased temperatures due to climate change (Song *et al.*, 2004; Osman-Elasha, 2009; Awange *et al*., 2013).

The study further established from focus group discussants that increases in temperature have largely contributed to changes in rainfall patterns, hence; climate change. This is because the main driver of seasons is solar energy, such that with climate change there is differential heating of the water bodies and the earth surface(Song *et al*., 2004). Through the water bodies we get water vapour, hence; there is a relationship between temperature and climate change (Serdeczny *et al*., 2016; personal communication with Migori County Director for Meteorological Services, July 2017).

The study further established from focus group discussions that whereas the total amount of rainfall has more or less remained constant, comparing the 60's-2000 and the period after 2001, there has been remarkable changes in its onset, seasonality, distribution (spatial and temporal) and intensity. Rainfall in the study area as from the year 2001 is very erratic, with delayed onset (for the long rains), having higher intensities, and of uneven distribution compared to the 1960s. Often there is no clear distinction between the long and short rainy seasons, with the latter sometimes being more reliable than the former. These findings were further corroborated by Migori County Director of Meteorological Services and USAID (2012), and are consistent with other study findings (Osman-Elasha, 2009; Serdeczny *et al*., 2016; Fadina & Barjolle, 2018), regrading higher rainfall over eastern Africa, but with distortions in the duration of the rainy seasons and the variability of the onset of rainfall, as the climate continues to change. The findings, however, differ from those of Song *et al*., (2004), who predicted that the effect of a large body of water (Lake Victoria)would causes increases in temperatures over the south-western region of the Lake, but this would not result into a corresponding increase in precipitation, due to the effect of a south-easterly wind. The projections by Tedesse & Dereje (2018)over Eastern African region experiencing more dry spells are also inconsistent with the study findings, although are consistent in other parts of Kenya and Eastern Africa.

What is emerging in Migori County, as in most parts of Kenya; therefore, is that despite a slight increase in rainfall amount over time since 2001, the rainfall amount received over the short rainy seasons has been much higher, sometimes even proving to be more reliable, and well distributed (spatial and temporal) compared to the long rainy seasons (UNDP, 2012; AfDB, 2020). This implies that the major issue around Migori County is coping with increased amounts of precipitation and higher temperatures. These could lead to disappearance of some crop and livestock species, hence; reduced forage amounts and variability for livestock(Rojas-Downing et al., 2017). Besides, there is a likelihood of emergence of new strains of crop and livestock diseases and pests that may be difficult to manage (Amamou *et al*., 2018; Tedesse & Dereje, 2018; Simotwo *et al*., 2018). This would ultimately lead to reduced returns on investment form smallholder dairying (Korkmaz, 2018; GEF, 2020; FAO, 2020). There would also be the challenge of getting the right cultivars and livestock breeds that would adapt to that kind of climate and remain in production under such harsh conditions (Climate Chance, 2019; CGIAR, 2020).

4.4.2.2 Influence of farmers’ perceptions on climate change adaptation

Available evidence point to the fact that climate change has taken place in Migori County, just as is the case in other parts of Southwestern Kenya, Kenya, Sub Saharan Africa, and the World (Simotwo *et al*., 2018; Harvey et al., 2018; Marie *et al*., 2020). For smallholder dairy farmers of the study area, Kenya and the rest of the tropical world, what is critical is how the perceived changes affect the dairy industry, and in-turn, their livelihoods(One Acre Fund, 2020). How the changes affect their livelihoods would be seen on how they adapt to the climate change effects(Smit & Pilofosova, 2018).

Tables 21 and 22 summarize the influence of the respondents’ perceptions of climate changes on adaptation. As shown in Table 21, the study respondents’ perception that there was no change in night temperature had a slight, but significant influence on their choice to rear adaptable non-Friesian breeds and their crosses (Adjusted Odds=0.08; p=0.02), while the perception that night temperatures had decreased had a s slight, but significant influence on their choice to practice mixed crop and dairy farming (Adjusted Odds=0.13; p=0.04). Regarding rainfall, the perception that the spatial and temporal distribution of the short rains got worse had a very slight, but significant influence on respondents’ choice to establish own fodder (Adjusted Odds=0.02; p=0.01). From Table 22, the study the respondents’ perception that there is no remarkable change in day temperatures (Adjusted Odds=0.05; p=0.02) and that day temperatures had somehow decreased (Adjusted Odds=0.02; p=0.02), both had a significant influence on realization of an increasing trend in income from milk sales. In the same Table, study respondents’ perception that rainfall seasons have remained the same (Adjusted Odds=0.02; p=0.00), and that the length of the rainfall seasons have reduced (Adjusted Odds=0.10; p=0.03), both had a significant influence on the number of dairy cattle kept by the respondents. Regarding rainfall, Table 22 shows that respondents’ perception that the onset of the short rains is very unpredictable (Adjusted Odds=0.37; p=0.04) significantly influenced the realization of an increasing trend in income from milk sales. Moreover, study respondents' perception that the rainfall duration in a single rainy episode (rainfall event) during the long rains has not changed (Adjusted Odds=0.01; p=0.03) and that the rainfall intensity during the long rainy season has increased (Adjusted Odds=0.01; p=0.01), both significantly influenced the number of dairy cattle kept by the study population.

The study findings indicate weak, but significant associations between the study respondents' perceptions on temperature and rainfall on climate change adaptation. The findings, which were also corroborated by Migori County Meteorological Officer, are consistent with those of other scholars (Tripathi & Mishra, 2017; Tedesse & Dereje, 2018). Nevertheless, the findings, differ with findings of several other studies (Ogalleh *et at.*, 2012; Wamugi, 2016; Simotwo *et al*., 2018) that rainfall amounts were generally decreasing. The statistically significant relationships between the study respondents' perceptions of temperature and rainfall, in particular; differ with findings by Mudombi-Rusinamhodzi *et al*., 2012, who noted that respondents' perceptions had no statistically significant relationship with climate change adaptation. Their argument was that all their study respondents were aware of climate variability, which was not the case for Migori.

Even though several modelling studies have predicated increasing extremities in weather patterns, such patterns as droughts and flood (Shah, 2015; Rojas-Downing, 2017; FAO, 2020), none of these were reported in the study area; except heavy erosion and strong wind storms that end up destroying crops and property. This is consistent with several findings (Kasulo *et al.*, 2012; Ihemezie *et al*., 2018).

Generally, the smallholder dairy farmers would respond to the climatic changes in a manner that would both reduce their exposure to weather risks (Kasulo *et al*., 2012; Akhter & Olaf, 2016; Mutunga *et al*., 2017;) and ensure their sustainability in the dairy industry (Shah, 2015; CGIAR, 2020). This would assure the County of food and nutrition security and diversity, and reducing poverty (Akhter & Olaf, 2016). The study respondents responded to the climate changes by adopting a number of soft, predictive and reactive adaptive measures, including adopting mixed crop and livestock farming, semi-intensive dairy production system, relying on household members for labour in the dairy enterprise, reducing dairy herd size to 2 cattle, establishing own fodder, rearing cross breed dairy cattle, keeping non Friesian breeds and their crosses that are more adaptable to local conditions, and ensuring an increasing trend in income from milk sales (Figure 10). Similar findings have been reported elsewhere, particularly for mixed farming, rearing of cross breed cattle, adaptable breeds, using household labour and establishing own fodder (Bagamba *et al*., 2012; Tedesse & Dereje, 2018; Marie et al., 2020). The study findings, however, differ with findings of other scholars (Gbetibouo, 2009), where, even though the farmers perceived climate was changing, two thirds did not make any efforts to adapt to the effects.

Hitayezu & Ortmann (2017) posit that the likelihood of perceiving climate as changing is associated with both personal experience and analytical processing of climate information. Thus, considering the fact that most of the Migori smallholder dairy farmers only had basic education, this would be expected to limit their ability to effectively process and critically analyse climate information; but this was not the case as they developed an effective impression on the changes in the climate of the area and the need to adapt (Hitayezu & Ortmann, 2017). This could be associated with individual farmers' worldview, exposure to climate information from various sources, and support the farmers have received from different institutions to help them adapt (Fadina &Barjolle, 2018; GEF, 2020; CGIAR, 2020). The study respondents being smallholder farmers, are very vulnerable to climate change, since they are in the tropics, and with various socio-economic, demographic, and policy trends that limit their capacity to adapt to climate change (Ogalleh *et al.,* 2012; Merton, 2017; Ihemezie *et al*., 2018).

4.5 Smallholder dairy farmers' knowledge and climate change adaptation

4.5.1Results

4.5.1.1 Knowledge on climate changes and climate change effects

Out of the 15 questions, the minimum score (n=367) was 4 (or 26%), while the maximum was 15 or 100%), with a mean of 9.49 (or 63%) and a standard deviation of 2.96 (or 19.89%)**.** The proportions of smallholder dairy farmers' knowledge level of climate change are presented in Figure 10. Figure 10 shows that the smallholder dairy farmers have high knowledge of climate change and how it affects smallholder dairying; with 60.8% of the respondents scoring above average and 39.2% scoring below average (n=367).

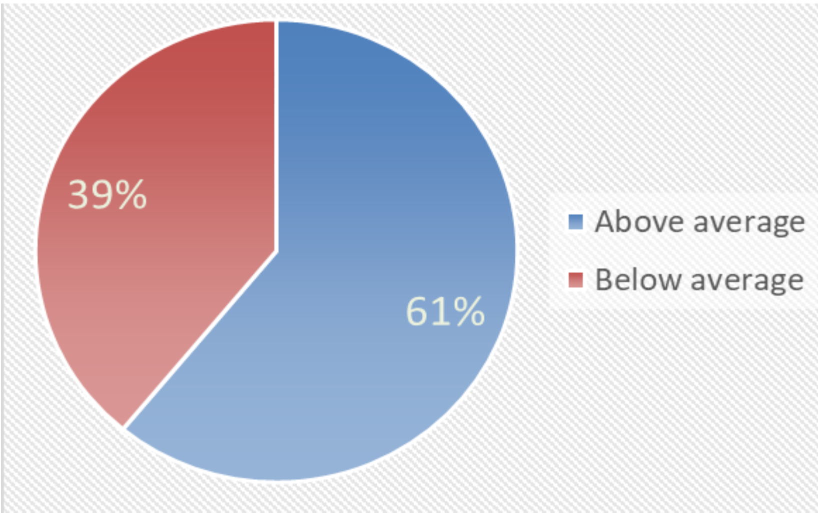

Figure 10: Distribution of study respondents by level of climate change knowledge (n=367)

Even though in overall about 61% of the study respondents scored above-average in terms of knowledge of climate change and its effects, 31% (or 114 respondents) scored 46% (i.e. 7/15), which is below average as shown in Table 23. Cumulatively, about 52% (or 192 of the respondents) scored 53% (or 8/15), which is considered average. Cumulatively, about 81% (or 297) of the respondents scored 80% (or 12/15); with about 12% (or 43) of the respondents scoring 100% (i.e. 15/15).

Table 23: Distribution of study respondents by score on knowledge (n=367)

Frequency of respondents	% of respondents	Total Score (Out of 15)	Total Score (%)	Cumulative frequency of respondents	Cumulative %
1	0.3	4	26	1	0.3
6	1.6	5	33	7	1.9
23	6.3	6	40	30	8.2
114	31.1	7	46	144	39.2
48	13.1	8	53	192	52.3
22	6.0	9	60	214	58.3
14	3.8	10	66	228	62.1
36	9.8	11	73	264	71.9
33	9.0	12	80	297	80.9
23	6.3	13	86	320	87.2
4	1.1	14	93	324	88.3
43	11.7	15	100	367	100.0
367	**100.0**	**Total**	**100**		

In terms of performance per individual question, Table 24 shows that the question where majority (93.5%; n=367) of the study respondents scored right was the question regarding feed availability (question 1), while the question where majority of the study respondents (67%; n=367) scored wrong was the question on dairy cattle adaptation to local conditions (question 14).

Table 24: Distribution of respondents by knowledge by question (n=367)

Qn #	Question	Correct response (Yes/No)	Study respondents' responses					
			Yes		No		Correctly responding	
			Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**
1	Disappearance of some forages (shrubs and herbs)	Yes	343	93.5	24	6.5	**343**	**93.5**
2	Emergence of some poisonous forages.	Yes	323	88	44	12	**323**	**88**
3	Difficulties in controlling common dairy cattle parasites using conventional acaricides alone.	Yes	316	86.1	51	13.9	**316**	**86.1**
4	Complications in dairy cattle disease management.	Yes	321	87.5	46	12.5	**321**	**87.5**
5	Drop in milk production from dairy cattle.	Yes	286	77.9	81	22.1	**286**	**77.9**
6	Changes in available water and its quality for dairy cattle.	Yes	285	77.7	82	22.3	**285**	**77.7**
7	Reduced adaptability of dairy cattle breeds to local conditions.	Yes	246	67	121	33	**246**	**67**
8	No significant effect on the number and types of forages available for dairy cattle in this community.	No	144	39.2	223	60.8	**223**	**60.8**
9	No significant effect on water availability for dairy cattle in this community.	No	166	45.2	201	54.8	**201**	**54.8**
10	No significant effect on dairy cattle parasites.	No	139	37.9	228	62.1	**228**	**62.1**
11	No significant effect on dairy cattle diseases.	No	141	38.4	226	61.6	**226**	**61.6**
12	No significant effect on milk production from dairy cattle.	No	163	44.4	204	55.6	**204**	**55.6**
13	No significant change in income earned from milk sales.	Yes	205	55.9	162	44.9	**205**	**55.9**
14	Little effect on dairy cattle adaptability.	No	246	67.0	121	33.0	**121**	**33.0**
15	Farmers unable to deal with climate change effects.	No	160	43.6	207	56.4	**207**	**56.4**

Table 25 presents a summary of some indigenous technical knowledge that emerged in the process of engaging focus group discussants for their perceptions regarding climate changes and its effects on dairying in the study area.As Table 25 indicates, the community has very rich indigenous technical knowledge (ITK), which is being employed in weather and climate forecasting and adaptation. This knowledge revolves around observing changes in wind directions and patterns, absence of some birds that used to herald beginning of rainy seasons, changes in types of sound produced by thunder, changes in water levels of water bodies, disappearance of certain forage types, and body feelings of some people with certain underlying conditions; whose bodies would pain all over to herald beginning of rainy seasons and vice-versa; as well as traditional rain-makers who would be consulted for divine interventions.

Table 25: Summary of indigenous knowledge on climate change effects

Knowledge area on climate change effect	**Key statement**	**Category of discussant**
Rainfall seasons	*"In the '60's and up the year 2000, the Westerly wind indicated the onset of dry spells, while Easterly wind heralded the onset of rainy seasons. Thecommunity would observe flight patterns of some black bird, water levels in wells, etc. to predict onset of rainy seasons. As from 2001 onwards, seasons are not very easy to predict.."*	Elders
	"In the '60s and up to around 2000 some villagers (especially the sick ones) would indicate by their feelings whether rains are about to fall or not. People would also observe certain physical features, such as natural vegetation-including such trees as Orembe, Bongu, Yago, Amboro, Maembe, and Ochuoga	Farmer groups and Dairy Farmers' Cooperative Society
Dairy cattle feeds and feeding	*" Since 2001, several grass and pasture species have disappeared".*	Elders
	"Some livestock feeds are no longer available, especially since the year 2001. Instead, there are new varieties of pastures, e.g. Boma Rhodes, Desmodium, etc. Nevertheless, farmers have tended to over-depend on Napier grass, feeding it green. This increase roughages and water content, thereby reducing milk production. Dry feeds on the other hand, help to increase milk production due to increased water intake (About 90% of milk being water)".	Farmer groups and Dairy Farmers' Cooperative Society
Water quantity & quality	*"Since 2001, amounts of water available for cattle have decreased as much of the water drains to the Lake; pollution of the water bodies is also high, hence; the quality is also low, as a result of chemicals discharged from sugar factories".*	Elders
	"After the year 2001, due to increases in population and land cultivation, areas that used to provide water for livestock have been cultivated. People also tend to cultivate the river rine areas. This has affected the quantity and quality of water available for livestock. Most farmers have had to sink their own shallow wells."	Farmer groups and Dairy Farmers' Cooperative Society
Milk production	*"In the '60s and up to the year 2000, there was much milk, but less income. As from 2001, there has been less milk, but much more income because the price per litre of milk is much higher".*	Elders
	"A lot of milk used to be available from local cattle in the 60's and 70's, but as of the period after 2001; despite increased number of grade cattle, total milk production has gone down; even though production per cow has gone up".	Farmer groups and Dairy Farmers' Cooperative Society
Adaptability of dairy breeds to local conditions	*"In the '60s and up to around the year 2000, Zebu cattle used to be well adapted and were fairly highly producing. Since 2001 there has been a shift to dairy intensification, with increased milk production, but reduced adaptability to local climatic conditions. Moreover, farmers are tending to go for Ayrshire crosses, as Friesians have tended to be susceptible to tse-tse flies".*	Farmer groups and Dairy Farmers' Cooperative Society
Production system	*"Most farmers have since the year 2001 tended to practice a mixture of zero-grazing and tethering, but not free range that exposes cattle to tick-borne diseases".*	
Diseases and parasites	*"There has been increased prevalence of ticks and tick-borne diseases since 2001. Diseases like ECF are now difficult to treat. Farmers have been advised to alternate the acaricides so as to break tick resistance. Most of the acaricides are no longer effective, with use of wrong application method or appliances."*	

4.5.1.2 Relationship between knowledge and climate change adaptation

A summary of knowledge measures with significant relationship with study respondents' climate change adaptations relating to farming type, production method, and establishment of own fodder is presented in Table 26 ($p<0.05$). Table 26 indicates that adoption of mixed farming could potentially be influenced by knowledge that climate change affects forage availability (Crude Odds=0.12; p=0.04); has an effect on parasites (Crude Odds=0.13; p=0.05) and on diseases (Crude Odds=0.13; p=0.05) of dairy cattle; affects milk production (Crude Odds=0.10; p=0.03); and that dairy farmers are capable of dealing with climate change effects (Crude Odds=0.10; p=0.03). It could also potentially be influenced by the aggregate score of farmers' knowledge in climate change effects (Crude Odds=0.18; p=0.01). These influences were, however, insignificant when all knowledge measures were jointly considered.

Similarly, the practice of non-intensive dairy production could potentially be influenced by knowledge of the fact that climate change affects available forage (Crude Odds=0.18; p=0.02), and that dairy farmers are capable of dealing with climate change effects (Crude Odds=0.24; p=0.03). This influence was, however, insignificant when all knowledge measures were jointly evaluated.

Regarding adoption of own fodder climate change adaptive strategy, Table 26 shows that the establishment of own fodder could potentially be influenced by knowledge of the fact that climate change has an effect on available forages (Crude Odds=0.33; p=0.01) and available water (Crude Odds=0.08; p=n/a). It could also potentially be influenced by knowledge of the fact that climate change affects parasites (Crude Odds=0.36; p=0.01) and diseases of dairy cattle (Crude Odds=0.44; p=0.04) and milk production (Crude Odds=0.35; p=0.01).

Similarly, establishment of own fodder could potentially be influenced by knowledge of the fact that climate change affects earnings from dairy cattle (Crude Odds=0.19; p=n/a); adaptation of dairy cattle to local conditions (Crude Odds=0.14; p=0.01); and that farmers are capable of dealing with climate change effects (Crude Odds=0.34; p=0.01). These influences were, however, insignificant when all knowledge measures were jointly evaluated.

Table 26: Relationships between Knowledge and Farming type, Production method and Own Fodder as Climate Change adaptive strategies

Knowledge of climate change effect	Crude Odds (95% C.I.)			Adjusted Odds (95% C.I.)		
	Odds	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**
Knowledge of climate change effect and Farming Type Adaptive Strategy						
No effect on available forages (Yes)						
No*	**0.12**	**0.02-0.96**	**0.04**	Ref.	Ref.	0.25
No effect on parasites of dairy cattle (Yes)						
No*	**0.13**	**0.02-1.01**	**0.05**	Ref.	Ref.	0.38
No effect on diseases of dairy cattle (Yes)						
No*	**0.13**	**0.02-0.99**	**0.05**	Ref.	Ref.	0.28
No effect on milk production (Yes)						
No*	**0.10**	**0.01-0.77**	**0.03**	Ref.	Ref.	0.34
Dairy farmers can't deal with climate change effects (Yes)						
No*	**0.10**	**0.01-0.79**	**0.03**	Ref.	Ref.	0.32
Total Score Category (Below Average)						
Above Average*	**0.18**	**0.05-0.68**	**0.01**	0.36	0.01-11.32	0.56
Knowledge of climate change effects and Production Method Adaptive Strategy						
No effect on available forages (Yes)						
No*	**0.18**	**0.04-0.80**	**0.02**	1.21	Ref.	0.98
Dairy farmers can't deal with climate change effects (Yes)						
No*	**0.24**	**0.07-0.86**	**0.03**	1.78	Ref.	0.94
Knowledge of climate change effects and Own Fodder Adaptive Strategy						
No effect on available forages (Yes)						
No*	**0.33**	**0.15-0.73**	**0.01**	14.93	Ref.	0.66
No effect on water available (Yes)						
No*	**0.08**	**0.02-0.29**	**n/a**	1.56	Ref.	0.94
No effect on parasites of dairy cattle (Yes)						
No*	**0.36**	**0.16-0.80**	**0.01**	39.18	Ref.	0.55
No effect on diseases of dairy cattle (Yes)						
No*	**0.44**	**0.20-0.96**	**0.04**	64.60	Ref.	0.50
No effect on milk production (Yes)						
No*	**0.35**	**0.15-0.80**	**0.01**	38.46	Ref.	0.55
No effect on earnings from dairy (Yes)						
No*	**0.19**	**0.06-0.56**	**n/a**	21.49	Ref.	0.62
Dairy cattle still well adapted (Yes)						
No*	**0.14**	**0.03-0.61**	**0.01**	9.57	Ref.	0.72
Dairy farmers can't deal with climate change effects (Yes)						
No*	**0.34**	**0.15-0.77**	**0.01**	42.26	Ref.	0.55

Table 27 presents a summary of the findings for relationships between farmers' climate change knowledge and the breeds of dairy cattle kept, number of dairy cattle kept, main source of labour, and dairy income trend as climate change adaptive strategies. Table 27 shows that adoption of crossbred cattle and use of family labour could all potentially be influenced by total score (Crude Odds=0.81; p=n/a) and percentage score (Crude Odds=0.97;

p=n/a); and scores above average (Odds=0.08; p=0.01), respectively. These influences were, however, insignificant when all the knowledge measures were jointly considered. Farmers observing an increasing trend in income from milk sales could potentially be influenced by knowledge that climate change affects forage (Crude Odds=0.35; p=n/a) and water (Crude Odds=0.16; p=n/a) availability. It could also potentially be influenced by knowledge that climate change affects parasites (Crude Odds=0.18; p=n/a) and diseases (Crude Odds=0.24; p=n/a) of dairy cattle. In a like manner, the increasing trend in income from milk sales could potentially be influenced by knowledge that climate change affects milk production (Crude Odds=0.18; p=n/a); earnings from milk sales (Crude Odds=0.13; p=n/a); dairy cattle adaptability to local conditions (Crude Odds=0.07; p=n/a); and that farmers are capable of dealing with climate change effects (Crude Odds=0.32; p=n/a). These influences were, however, insignificant when all the knowledge measures were jointly examined. Thus, when jointly examined, only above average scores significantly influenced farmers to reduce herd sizes to 2 (Adjusted Odds=0.11; p=0.02).

Table 27: Relationships between Knowledge and Dairy cattle types, Number of dairy cattle kept, Main source of farm labour, and Trend in dairy income as climate change adaptive strategies

Knowledge of climate change effect	**Crude Odds (95% C.I.)**			**Adjusted Odds (95% C.I.)**		
	Odds	**C.I**	**P-value**	**Odds**	**C.I**	**P-value**
Knowledge of climate change effects and Dairy Cattle Types Adaptive Strategy						
Total score*	**0.81**	**0.73-0.90**	**n/a**	n/a	n/a	n/a
% Score*	**0.97**	**0.96-0.98**	**n/a**	2.09	0.52-8.46	0.30
Knowledge of climate change effects and Number of Dairy Cattle kept Adaptive Strategy						
Total Score Category (Below Average)						
Above average*	1.15	0.51-2.57	0.74	**0.11**	**0.02-0.72**	**0.02**
Knowledge of climate change effects and Main source of farm labour Adaptive Strategy						
Total Score Category (Below Average)						
Above average*	**0.08**	**0.01-0.57**	**0.01**	n/a	n/a	1.00
Knowledge of climate change effects and trend in dairy income Adaptive Strategy						
No effect on available forages (Yes)						
No*	**0.35**	**0.21-0.57**	**n/a**	0.14	Ref.	0.64
No effect on water available (Yes)						
No*	**0.16**	**0.10-0.28**	**n/a**	0.59	Ref.	0.90
No effect on parasites of dairy cattle (Yes)						
No*	**0.18**	**0.10-0.32**	**n/a**	0.86	Ref.	0.97
No effect on diseases of dairy cattle (Yes)						
No*	**0.24**	**0.14-0.41**	**n/a**	0.30	Ref.	0.77
No effect on milk production (Yes)						
No*	**0.18**	**0.11-0.31**	**n/a**	0.45	Ref.	0.85
No effect on earnings from dairy (Yes)						
No*	**0.13**	**0.08-0.22**	**n/a**	0.68	Ref.	0.93
Dairy cattle still well adapted (Yes)						
No*	**0.07**	**0.04-0.11**	**n/a**	1.76	Ref.	0.89
Dairy farmers can't deal with climate change effects (Yes)						
No*	**0.32**	**0.20-0.53**	**n/a**	0.37	Ref.	0.82

4.5.2 Discussions

Smallholder dairy farmers' knowledge on climate change effects could come from farmers' educational background, exposure to climate change information, interaction with other farmers through social networks and experience in dairy farming(Jairo & Korir, 2019). With knowledge comes exposure to new ideas, skills and information (Akhter & Olaf, 2016;

Tripathi & Mishra, 2017; Tegegne, 2017) that would enable the farmer to make rational decision to adopt climate change adaptation technologies or strategies (Mashiza, 2019). In this study, although about 61% of the respondents scored above average on knowledge of climate change effects, giving the impression that the study respondents had high level of knowledge on climate change and its effects on smallholder dairying; as many as 31% of the respondents scored only 46%, which is below average. This could be an indication of the fact that through farmers' educational background, interaction with both formal and informal sources of climate change information, and own experience (Tripathi & Mishra, 2017; Jairo & Korir, 2019), study farmers had gained some critical level of knowledge on climate change and climate change effects on smallholder dairying in the study area. However, the fact that 31% of the respondents scored below average also indicates that climate change is still an emerging challenge in the study area(Bagamba *et al*., 2012; Banerjee, 2015; Tedesse & Dereje, 2018) for which smallholder dairy farmers need concerted support from all stakeholders (Newsham *et al*., 2011; Safdar *et al*., 2017; Steiner *et al*., 2020). The high (or above-average) level of knowledge of the study respondents on climate change and its influence on the smallholder dairy industry is consistent with findings by Babatolu & Akinnubi (2016), Ochieng (2015, and Ogalleh *et al*., (2012) that famers have an in-depth knowledge of climatic variability, enabling them to make rational decisions regarding coping and adaptive strategies. It is worth noting that the rich indigenous knowledge existing within the community is also useful in complementing conventional knowledge on climate change and climate change adaptation, and could explain the high level of climate change adaption discussed in section 4.1.This is consistent with recommendations by Newsham *et al*. (2011) and Mashiza (2019) on the value of indigenous knowledge on climate change perceptions and adaptation, and the need to integrate this with conventional knowledge in recommending sustainable adaptation practices and formulating sound climate change adaptation policies and plans (Mashiza, 2019).

The high level of knowledge among Migori smallholder dairy farmers was also found to have a significant relationship with climate change adaptation. Total score (above average) significantly influenced the number of dairy cattle kept (Adjusted Odds=0.11; p=0.02). This implies that the overall level of knowledge smallholder dairy farmers have of climate change and its effects on dairying is the most important determining factor regarding knowledge's influence on smallholder dairy farmers' climate change adaptation. This is consistent with findings by Ogalleh *et al.* (2017), yet strengthening the findings by Bagamba *et al*. (2012) that there is still a considerable knowledge gap on climate change impact, vulnerability, and adaptation to climate variability and change. Ogalleh *et al*. (2012) took note of the fact that knowledge of climatic perceptions and adaptations are vital entry points for decision making, implying that despite not being so very learned (section4.2), Migori farmers' based on their worldview (perceptions), experience and knowledge of climatic changes and their impact on smallholder dairying; have managed to adapt fairly well to climate change effects. Generally, knowledge of climate change and its effects on smallholder dairying tended to have more influence on smallholder dairy farmers' choice of adaptive strategies related to farming and production system, breed choice, and feeding strategy; and ended up enabling them to experience an increasing trend in income from sale of milk from the dairy cattle (Amuge & Osewe, 2017; Steiner, 2020).

These findings suggest that there is a direct and positive relationship between knowledge and climate change adaptation, unlike what Tripathi & Mishra (2017) established in India. The adaptive practices that are most directly and positively influenced by knowledge include:

mixed crop and dairy farming, keeping of non-pure (i.e. crosses) dairy cattle breeds, and adoption of the household as main source of farm labour. This further confirms the hypothesis that farmers' decision making is complex and is based not only on their perceptions, but also on their knowledge and experience regarding the aspect of farming (Hassan & Nhemachena, 2008; Rojas-Downing et al., 2017; Fadina & Barjolle, 2018).

Moreover, knowledge about what farmers could do to adapt to climate change effects, and the effect of climate change on adaptability of breeds to local conditions, available forage, water, parasites and diseases of dairy cattle; milk yields, and earning from dairy farm through milk sales; directly and positively influenced Migori smallholder farmers' adaptive practices to climate change effects. The study findings agree with those of Ogalleh *et al.* (2012), but contradict findings by Hitayezu & Ortmann(2017).

Knowledge on climate change by the respondents could be a complex process that is influenced by farmers' age, educational level, experience in smallholder dairying, the strength of the farmers' social networks, and formal and informal access to climate change information (Newsham *et al*., 2011; Jairo & Korir, 2019; Mashiza, 2019)

4.6 Institutional support and smallholder dairy farmers' climate change adaptation

4.6.1 Results

4.6.1.1 Farmers' institutional support for climate change adaption

Table 28 presents the proportions of the study respondents by their sources of information regarding climate change and climate change adaptations (with multiple responses allowed). As shown in the Table, majority (91.0%; n=367) of the study respondents obtained climate change information from the radio, government extension agents (90.7%; n=367), other farmers (78.5%; n=367), television (75.5%; n=367), private extension agents (71.4%; n=367), and newspapers and pamphlets (70.3%; n=367). Government research institutions

(55.0%; n=367) also play a crucial role in climate change adaptation technology dissemination.

Table 28: Respondents by climate change information sources (n=367)

S/No.	Source of climate change information	Percentage of respondents accessing
1.	Government extension agents	90.7
2.	Private extension agents	71.4
3.	Government research institutions	55.0
4.	Public universities	29.7
5.	Private universities	25.9
6.	Other farmers	78.5
7.	Radio	91.0
8.	Television	75.5
9.	Newspapers and pamphlets	70.3
10.	Internet	29.4

The focus group discussants further indicated the specific institutions supporting smallholder dairy farmers in climate change adaptation and the kind of support they provided, as summarized by Table 29. From the Table, most farmers tended to have benefitted from Radio Citizen’s *Chapa Kazi* extension programme. Besides farmers benefited from extension services provided by several public, non-governmental and private organizations; such as Ministry of Agriculture, Livestock and Fisheries Development (MoALFD) and its associated programmes and livestock development farms (Oyani and Lichota), The International Centre for Insect Physiology and Ecology (ICIPE), International Livestock Research Institute (ILRI), Kenya Agricultural and Livestock Organization (KALRO), One Acre Fund, Heifer Project International (HPI), Community Mobilization Against Desertification (C-MAD), and commercial banks (KCB, Equity, and Family Bank). Nevertheless, people with indigenous knowledge on climate change provide unconventional climate change information as seen in Section 4.4.

Table 29: Institutions supporting dairy farmers in climate change adaptation

Institutional supporting smallholder dairy farmers of Migori County	Type of support provided
Migori County Government	Purchased and distributed 300 in-calf dairy cows to farmers
Kenya National Government	Plans to install a Milk Cooling Plant to a Farmers' Group in Uriri Sub-county.
Ministry of Agriculture, Livestock & Fisheries Development (MoALFD)	Provides extension and veterinary services to farmers.
Oyani LIC	Extension services on fodder establishment; On-farm demonstrations; Supply of fodder seeds; and provision of improved animals for breeding
National Accelerated Input Accessibility Programme (NAIAP)	Promotes improved dairy cattle feeding, mainly in Rongo.
Lake Basin Development Authority (LBDA) Lichota Technical Transfer Centre	Extension services and sale of improved dairy cattle to farmers.
NURU International	Promotes milk value addition (Yoghurt, Maziwa Mala, Maziwa Lala, etc.) in Isibania Ward of Kuria West Sub County.
Agriculture Sector Development Support Programme (ASDSP)	Coordinate stakeholder engagement selected value chains (Cow milk, Sweet potato, and Fish).
International Centre for Insect Physiology and Ecology (ICIPE)	Push-Pull Technology, involving control of maize stock-borer through cultivation of Napier grass and Desmodium as strips within a maize farm.
International Livestock Research Institute (ILRI)/ USAID	Collection of blood samples for laboratory testing so as to improve resistance of livestock to diseases and parasites. Supports in Synchronization of fertility for improved productivity of the dairy cattle. Also promotes milk value chain through support in livestock feeding, whereby it provides seeds of fodder crops, such as *Mlato-2 and Piata;* as well as capacity building through exposure tours.
Kenya Agricultural and Livestock Research Organization (KALRO)	Promotes yellow-fleshed sweet potatoes as dairy cattle feed.
USAID-CAVES	Promotes input supplies; capacity building on animal husbandry, A.I services, and human health-through APHIAPlus.
Heifer Project International (HPI)	Gave 300 dairy cattle in Rongo and Awendo Sub counties.
Kenya Tsetse and Trypanosomiasis Eradication Campaign (KENTTEC)	Provides dairy cattle to farmers in Awendo & Rongo sub counties.
Agricultural Society of Kenya (ASK)	Annual dissemination of information to farmers.
Citizen Radio (*Chapa Kazi* Programme)	Radio talk show to educate farmers on modern farming techniques.
Meteorological Department	Provides credible weather information through accurate forecasting.
Financial institutions (Family Bank, Equity Bank, and KCB)	Extension and credit services to farmers.
Insurance Companies	Insure crops and livestock.
Kenya Climate Smart Agriculture	Supports up-scaling of smart technologies on fodder production, water, data collection and interpretation.
One Acre Fund	Provides farm inputs (DAP& CAN fertilizers, solar light, canvas, seeds, storage bags), and promotes kitchen gardening on loan.
Community Mobilization Against Desertification (C-MAD)	Provide dairy cattle and capacity building to farmers.
Farmer groups and Dairy Cooperative Societies	Extension services; input acquisition and produce marketing; and passing on animals to other group members.
EAAPP	Extension services (through radio programme); support in feed formulation; training of farmers in dairy production; provision of seeds for animal feeds (e.g. Boma Rhodes)
Kenya Cooperative Creameries (KCC)	Buying milk from the Cooperatives; extension services; support in acquisition of milk equipment (e.g. coolers, pasteurizers, and milk dispensers) on loan; and corporate social responsibility
Kenya Dairy Board (KDB)	Regulation of the milk industry; Extension on milk quality, certification of milk selling outlets.

Table 30 presents a ranking, in order of priority, of the three most important sources of information that the study respondents access with regard to climate change and climate change adaptation in smallholder dairying. From the Table, government extension agents (50.4%; n=367), radio (38.1%; n=367), other farmers (17.2%; n=367), television (15.3%; n=367), and private extension agents (14.7%; n=367), were the most influential sources of information to farmers regarding climate change and climate change adaptation.

Table 30: Study respondents by ranked Climate Change information sources (n=367)

Climate change information source	**Percent respondents ranking**	**Rank**
Government extension agents	**50.4**	**1**
	6.5	2
	5.4	3
Radio	22.1	1
	38.1	**2**
	36.8	3
Other farmers	8.7	1
	17.2	2
	14.4	3
Private extension agents	6.8	1
	14.7	2
	8.4	3
Government research institutions	4.6	1
	10.6	2
	6.8	3
Internet	4.1	1
	1.4	2
	3.3	3
Newspapers & pamphlets	2.7	1
	6.0	2
	8.7	3
Television	0.5	1
	4.1	2
	15.3	**3**
Public universities	N/A	1
	1.4	2
	0.8	3

Regarding respondents' level of satisfaction with the information they obtained from their most preferred source of information regarding climate change and its effects on smallholder dairy farming in the community, majority (76.8%; n=367) indicated that they were satisfied, with only some 23.2% being dissatisfied.

4.6.1.2 Barriers to farmers' access to climate change information and adaptation

Even though adaptation level of smallholder dairy farmers of Migori County is generally high as already seen in section 4.1, both key informants and focus group discussants indicated that there were some gaps in the flow of information reaching farmers with regard to climate change and its effects. These impede smallholder dairy farmers' adaptation to climate change. They include unreliable weather fore-casting by the Meteorological Department and a section of the Mass Media; use of technical language in weather forecasting, such that famers are unable to correctly interpret some of the information; and inaccessibility to farm inputs, with most agrovets being located in urban centres such that farmers are unable to take effective and efficient adaptive responses.

Others gaps, barriers or challenges to climate change information effectively reaching the study farmers are; high illiteracy levels causing communication break-down; not many farmers have access to radio and television, hence; do not get the information passed through these channels; and ignorance among some of the farmers, who only purpose to seek for information when there is a serious problem in their farms or in the area. There is also low government extension staff capacity (in terms of numbers, technical knowledge on modern issues and facilitation, leading to erratic planning); weak research-extension-farmer linkages; and with the advent of County Government, limited forums for sharing information with farmers. These findings are summarized in Table 31.

4.6.1.3 Measures to improve farmers' climate change adaptation

The key informants and focus group discussants went ahead to recommend measures to improve the farmers' adaptation to climate change effects and the organizations serving in the study site that were better placed to provide the support. These findings are summarized in

Table 31. From Table 31, limited and irregular flow of information on climate change and adaptation, weak research-extension-farmer linkage, inadequate feed and water for dairy cattle, poor access to credit, high costs of farm inputs, poor access to fur-flung parts of the County, poor milk marketing, and lack of county environment action plan, are the key challenges to climate change adaptation.

Table 31: Improving smallholder dairy farmers' climate change adaptation

Constraints to farmers' adaptation to climate change effects	*Individuals/Institutions/Groups better placed to address them and how*
Limited and irregular information flow on climate change	KALRO, MoALFD, and Universities to step up research on climate change and its effects and ensure findings reach farmers adequately and in a simplified manner so as to improve dairying in Migori County.Rongo University plans to build an information centre for livestock production.
Weak Research-Extension-Farmer linkage	KALRO should step up research on livestock production to help in diversification from sugarcane production, that is bedeviled by delays in payment, which impoverishes the farmers.
Limited extension contact	More field days by private drug companies, e.g. Nobrook and other partners, e.g. ICIPE
Low quality A.I.	More research to improve quality of A.I services.
High expenses due to repeat A.I services.	County Government to spread A.I services to the entire County and train farmers on heat detection.
Inadequate feed resources	Sensitize farmers on dry feeding of dairy cattle as trained by ASDSP.
Inadequate and low-quality water	Farmers sinking own shallow wells/boreholes and do rain water harvesting.
Poverty and lack of working capital	Support farmer group formation and linkages with MFIs for sustainable access to financial services
Poor access to credit services	MFIs and commercial banks to support establishment of pasteurization plants on milk-credit.
High cost of farm inputs	Regulation-National Government, and legislation-County Assembly
Limited accessibility to rural areas, hence; loss of milk	County Government to improve road network to all parts of the County.
Weak cooperative movement, hence; loss of profit to middlemen.	Cooperative Department and County Government to promote formation of farmer groups and cooperative societies for effective milk marketing.
Inadequate/inappropriate forecasting equipment, e.g. Rain Gauges	Procurement by Migori County Government.
No land for weather forecasting station	Migori County Government should set aside land and funds for this.
Lack of County Environment Action Plan.	Migori County Government and partners should develop.
Lack of observatories for addressing weather situation and information.	Migori County Government to establish rainfall stations (i.e. automatic weather stations) in each of the 8 sub-counties.

4.6.1.4 Measures for improving farmers' access to climate change information

The study respondents suggested a raft of measures to further improve the usefulness of the information they obtain from various sources on climate change and adaptation. Table 32 presents a summary of the measures suggested, with multiple responses recorded. Table 32 shows that majority (97.8%; n=367) would increase frequency of access to most preferred source of information on climate change and adaptation. About 89% (n=367) indicated they would consult more and compare with fellow farmers, 79% (n=367) would look for information from other sources, while about 71% (n=367) would spend more quality time accessing information from their most preferred information source.

Table 32: Measures to improve Climate Change information usefulness (n=367)

Suggested measure to improve usefulness of climate change information	**Frequency (%of respondents who would adopt)**
Increase frequency of access	97.8
Diversify sources of information	79.3
Increase hours of personal contact with source	71.1
Consult more and compare with other farmers in the area	88.8
Trust more on personal intuition	33.5

When asked to categorize the suggested measures into two-i.e. improving access to information source and more consultations (the two most outstanding responses), all (100%; n=367) the study respondents indicated that they would make efforts to improve access to information on climate change and its effects on smallholder dairy farming. Majority (91%; n=367) indicated that farmers should make efforts to have more consultations with the sources of information on climate change and its effects.

4.6.1.4 Climate change information sources and climate change adaptation

Table 33 shows the relationship between climate change sources and the study respondents' adaptive strategies to climate change effects, with all climate change information sources jointly considered. Table 33 shows that respondents who did not get climate change information from government extension agents were likely to adopt crossbred dairy cattle by a factor of about 0.1 (Adjusted Odds=0.13; p=0.01). Respondents who did not get the information from other farmers were likely to adopt crossbred dairy cattle by a factor of about 0.2 (Adjusted Odds=0.17; p=0.01). Among respondents who ranked government extension agents as the most important source of information on climate change and adaptation, contact with government research institutions (e.g. KALRO, ILRI) was found to influence adoption of crossbred cattle by a factor of about 0.04 (Adjusted Odds=0.04; p=0.00).

Similarly, the respondents who did not have access to climate change information from television were about 0.3 times more likely not to switch to non-Friesian breeds and their crosses (Adjusted Odds=0.31; p=0.04). Respondents who did not have contacts with Government extension agents were found to be about 0.2 times unlikely to have changed to rearing non Friesian and their crosses (Adjusted Odds=0.17; p=0.02). Among respondents who ranked Government extension agents as the first climate change information source, only contact with Government research institutions was found to have a significant influence on adoption of non-Friesian breeds and their crosses (Adjusted Odds=0.12; p=0.02).

The study established that with Government extension agents as the first ranked climate change information source, jointly examined, respondents who had access to climate change information from the internet were about 0.01 times more likely to reduce their herd sizes to 2 dairy cattle (Adjusted Odds=0.01; p=0.01). With Government extension agents as the second ranked climate change information source, the internet was found to influence by a factor of 0.02 the adoption of reducing herd size to 2 dairy cattle (Adjusted Odds=0.02; p=0.02). Considering the level of satisfaction with the information the respondents obtained from their most preferred climate change information source, the study established that when jointly examined with others, the respondents who were not satisfied were about 0.1 times likely to be reduce their herd size to 2 dairy cattle (Adjusted Odds=0.09; p=0.01).

When all the 10 climate change information sources were jointly evaluated, respondents that lacked access to newspapers and pamphlets were about 0.3 times more unlikely to observe an increasing trend in income earnings from the industry (Adjusted Odds=0.31; p=0.02). With Government extension agents as the first ranked climate change information source, the radio influenced observing an increasing trend in income from milk sales by about 0.1 (Adjusted Odds=0.07 p=0.00). With Government extension agents ranked third, respondents who had access to public universities providing information on climate change and its effect on smallholder dairying were 0.01 more likely to experience an increasing trend in earnings from smallholder dairying compared to their counterparts who did not (Adjusted Odds=0.01; p=0.02). When jointly examined, respondents who were not satisfied with the information they obtained from their most preferred source regarding climate change were about 0.1 times more likely to experience an increasing trend in income from milk sales (Adjusted Odds=0.10; p=0.00).

Table 33: Climate Change information sources and Climate Change Adaptation

Climate information source	Adjusted Odds (95% C.I)		
	Odds	**C.I**	**P-value**
Climate change information source and Production Method Adaptive Strategy			
Satisfaction level with information from most preferred source regarding climate change & its effects (Satisfied)			
Not satisfied	0.08	0.01-0.89	0.04
Climate change information source and Dairy Cattle Types Adaptive Strategy			
Government Extension agents (Yes)			
No*	0.13	0.03-0.62	0.01
Other Farmers (Yes)			
No*	0.17	0.05-0.60	0.01
3 most important sources-Rank 1(Gov't Ext. agents)			
Government Research Institutions*	0.04	0.00-0.40	0.00
Climate change information source and Dairy Cattle breeds kept Adaptive Strategy			
Government Extension agents (Yes)			
No*	0.17	0.04-0.78	0.02
TV (Yes)			
No*	0.31	0.10-0.95	0.04
3 most important sources- Rank 1 (Gov't Ext. Agents)			
Government Research Institutions*	0.12	0.02-0.69	0.02
Climate change information source and Number of dairy cattle Adaptive Strategy			
3 most important sources-Rank 1 (Gov't Ext. Agents)			
Internet*	0.01	0.00-0.34	0.01
3 most important sources-Rank 2 (Gov't Ext. Agents)			
Internet*	0.02	0.00-0.52	0.02
Satisfaction level with information from most preferred source regarding climate change & its effects (Satisfied)			
Not satisfied*	0.09	0.02-0.56	0.01
Climate change information source and Dairy income trend Adaptive Strategy			
Newspapers & pamphlets (Yes)			
No*	0.31	0.12-0.86	0.02
3 most important sources of information on climate change to farmers- Rank 1 (Gov't Ext. agents)			
Radio set*	0.07	0.02-0.24	0.00
3 most important sources of information on climate change to farmers-Ranks 3 (Gov't Ext. agents)			
Public Universities*	0.01	0.00-0.44	0.02
Satisfaction level with information from most preferred source regarding climate change & its effects (Satisfied)			
Not satisfied*	0.10	0.03-0.36	0.00

4.6.2 Discussions

4.6.2.1 Institutional support and smallholder dairying

Technology diffusion and adoption theory as postulated by Rogers (2003) is a complex process involving five different non-linear stages of awareness, interest, evaluation, trial, and then adoption. The awareness usually comes from several formal and non-formal sources of information (Hassan & Nhemachena, 2008; Elum *et al*., 2017; Jairo & Korir, 2019). It is for this reason that The Commonwealth Education Hub (2015) recommended that climate change should be addressed through the use of formal, non-formal and informal education targeting a cross-section of stakeholders, including farmers, communities, students, industries and governments

Scholars agree that farmers' educational background, experience and access to information pertaining to any technology (including climate change adaptation) play a critical role in informing their knowledge about the technology and whether to adopt it or not (Obayelu *et al*., 2017; Fadina & Barjole, 2018; Ihemezie *et al*., 2018; Smit &Pilifosova, 2018). Scholars (Okuthe, 2014; Prokopy *et al*., 2017; Jairo & Korir, 2019; Marie *et al*., 2020)note that farmers would obtain climate change information from a variety of sources, ranging from fellow farmers, mass media (radio and television), print media (newspapers, newsletters, pamphlets and brochures), electronic media (internet, mobile phones, etc.), social media platforms (Facebook, Histagram, Twitter, etc.), extension agents (both state and non-state), researchers, universities, and private organizations (mainly suppliers of agro-inputs, processers, and marketers).

4.6.2.2 Institutional support and smallholder dairy farmers' climate change adaptability

Stefanovi'c (2015) recognizes the fact that farmers' adaptation to climate change effect would be determined by access to extension services as it provides relevant agricultural adult education that would propel agricultural development. This supports findings by Ozor *et al*., (2010) that poor climate change information and agricultural extension service delivery is one of the major factors that constrain smallholder farmers from adapting to climate change impacts. Nevertheless, government extension service is faced with a number of challenges ranging from low numbers of staff to poor facilitation and remuneration, which makes it ineffective (Safdar *et al*., 2014; Mutunga *et al*., 2017; Smit & Pilifosova, 2018).Moreover, in Kenya, devolving agricultural extension services to the county governments with their own challenges has only worked to make matters worse for the ordinary smallholder farmer (Simotwo *et al*., 2018).In Kenya, therefore; participatory and farmer-focused, demand-driven group extension approach tailored along the farmer field school (FFS) approach is adopted by the Government to accelerate smallholder farmer access to agricultural information (Davis & Place, 2003). The advantage of FFS is that it allows for experiential learning by smallholder farmers, and provides a one-stop shop for interaction between researchers, extension agents (government, NGOs, and private) and farmers (Prokopy *et al*., 2017). This way, there is co-production of learning and sharing of experiences, lessons learnt and challenges; and using the synergy that arises out of the diversity of the expertise, experience and learning of the array of stakeholders involved, feasible solutions to the challenges are collectively worked out (Safdar *et al*., 2014; Prokopy *et al*, 2017). FFS, alongside other farmer-focused approaches, stress on participation, facilitation, partnerships and sustainability, even as farmers learn from among themselves (Davis & Place, 2003).

From this study, the radio (91.0%; n=367), government extension agents (90.7%; n=367), other farmers (78.5%; n=367), television (75.5%; n=367), private extension agents (71.4%; n=367), and newspapers and pamphlets (70.3%; n=367) were the main sources of information for farmers regrading climate change adaptation (Table 28). These findings were corroborated by those from key informants and focus group discussants who indicated that Migori smallholder dairy farmers obtain institutional support from the County Government; The National Government; Government Livestock Improvements Centres; Research Organizations, NGOs; and Private Institutions. Findings that better access to extension services would have a significant influence on climate change adaptation concur with findings of several scholars (Hassan & Nhemachena, 2008; Safdar *et al*., 2014; Muzamhindo *et al*., 2015; Muthui, 2015; Wamalwa, 2015; Fadina & Barjolle, 2018), but contradict findings by Mudombi-Rusinamhodzi *et al*., 2012; who argued that access to extension services had no significant influence on climate change adaptation responsiveness probably because in both districts of his study access to extension was high and both gender groups (females and males)had equal access to the extension services.

Study finding that other farmers was also a source of credible information to the study farmers regarding climate change and climate change adaption is not new (Odhiambo, 2014; Okuthe, 2014; Safdar *et al*., 2014), and further poses a great opportunity to use group extension approaches, like farmer groups and FFS to offer farmer advisory services to Migori farmers regarding climate change and climate change effects. Study finding that the mass media is popular with respondents in accessing climate change information and climate change adaption technologies is also consistent with other study findings (Jairo & Korir, 2019).

Table 30 indicates that government extension agents were ranked first (50.4%; n=367), Radio was ranked second (38.1%; n=367), while Television was ranked third (15.3%; n=367); with multiple responses being accepted, indicting the great role extension service plays in climate adaptation (Mutunga *et al.*, 2017; Bosire *et al*., 2019). Thus, with limited extension staff strengths, technical capacity, and facilitation; the media (particularly the radio and television) is increasingly playing an important role in providing vital information to farmers regarding climate change and dairying. Kirui (2014) also found the radio and TV to be the main sources of information on climate change among smallholder dairy farmers in Kosirai-Kenya and Namayumba-Uganda. This strengthens the great role played by mass media in the current dispensation in information transfer. This is even more critical in Kenya, where the Government has put a cap on employment of extension officers since the Civil Service Reform Programme of the year 2000.

As discussed in section 4.4, some unconventional sources of climate change information, arising from indigenous knowledge; such as observing nature (bird movements, leaf patterns of mangoes, etc.), listening to sound of thunder and consulting some people with certain health conditions, whose body would excessively pain at certain times also emerged. Information from such unconventional sources is then decoded by experts from the community before being disseminated to the general public through such forums as *Barazaas* (public meetings). This finding is consistent with other study findings (Newsham *et al*., 2011; Mashiza, 2019).

The fact that non-satisfactionwith level of information from the most preferred source of information regarding climate change and its effects had a statistically significant influence (Adjusted Odds=0.08; p=0.04) on climate change adaption (Table 33) could be a pointer to why the study respondents' level of knowledge (Figure 13) and adaptation (Table 10) was significantly high, despite not being so well educated (Figure 12). The reason is that, being unsatisfied with information from their most preferred source (government extension), the study respondents sought to fill this gap by other means; including other farmers, newspapers and pamphlets, radio and television. From the measures suggested by study respondents to improve the usefulness of information on climate change and climate change adaptation (Table 32), it is evident that farmers in the study area have a lot of interest in matters climate change and climate change adaptation. This explains why majority (97.8%; n=367) would prefer to increase their frequency of getting access to the information from the source, and only 33.5% (n=367) would consider trusting on their personal intuition. Since the Kenya Government's current extension policy is that of group extension approaches, that the farmers would consult more and compare with other farmers in the area (88.8%; n=367) resonates well with such extension modules as farmer field schools (FFS). This presents a great opportunity for the Government, private agencies, research institutions, private and public universities to work with the farmers to support them develop sustainable measures to adapt well to climate change effects currently being experienced and expected. The suggested measures to improve adaptability (Table 31) corroborate findings by other scholars (Hassan & Nhemachena, 2008; Bagamba *et al.*2012; Kirui, 2014; Smit & Pilifosova, 2018) that generally better access to extension services, climate change information and adaptation skills, technology and infrastructure, government policies and investment strategies, among others; would greatly improve smallholder farmers' adaptation to climate change in the Sub-Saharan African.

Table 31 also shows barriers to climate change adaption by the study respondents. These include; limited and irregular flow of information on climate change and adaptation, weak research-extension-farmer linkage, inadequate feed and water for dairy cattle, poor access to credit access, high costs of farm inputs, poor access to fur-flung parts of the County, poor milk marketing, and lack of county environment action plan, impede climate change adaptation. These are not unique to Southwesten Kenya. They are the common climate change adaptation challenges faced by smallholder dairy farmers in sub-Saharan Africa and the tropical world (Mutunga *et al.,*2017; Fadina & Barjolle, 2018; Marie *et al*., 2020) and confirms Simotwo *et al.* (2018) findings regarding the situation in Southwestern Kenya.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

In this Section, a summary of the study findings, conclusions and recommendations are discussed. Section 5.2 gives a summary of the major findings from the study, with Section 5.2.1 providing a general description of the summary of the study findings, while Section 5.2.2 summarizes the interrelationship between producer socio-demographics, their perceptions, knowledge and institutional support; and climate change adaptation. Sections 5.3 gives a highlight of the conclusions from the study as per the five study objectives. Section 5.4 describes the recommendations made from the study as per the study objectives. Section 5.5. gives the take away message from the study and the intervention logic in improving climate change adaptation in smallholder dairy systems. Finally, Section 5.6 highlights areas for further research.

5.2 Summary of Findings

Smallholder farming system in Kenya is practiced in mixed cop and livestock production, with mainly crossbred dairy cattle raised under semi-intensive production systems. The contribution of smallholder dairying to the local and national economy cannot be over-emphasized. Nevertheless, smallholder dairy farmers in Kenya face several challenges, of which climate change has become major in the 21st century, transcending boundaries, regions and economies; and presenting a problem with shifting goal posts. Ironically, regions that contribute least to climate change are the worst affected, owing to their low adaptive capacities and high vulnerability. Kenya is no exception to this.

While Kenya is self-sufficient in milk and milk products, there are local variations, with counties like Migori and most parts of South-western Kenya being milk-deficient and having to import milk and milk products from neighbouring counties to sustain local demand. Nevertheless, the supply of this milk import is often unreliable and its quality is unknown. This poses both a supply crisis, and more importantly, a health risk. Climate change comes in to complicate the situation even further. Local adaptation by smallholder dairy farmers would be key to ensuring there is sustained improvement in the quantity and quality of milk produced, thereby meeting household food, nutrition and income needs, and ensuring smallholder dairy industry in Kenya makes a sustained high level of contribution to the agricultural and national GDP.

This study sought to establish the factors that determine smallholder dairy farmers' climate change adaptation in Migori County. The study established that smallholder dairy farmers of the Migori County in Western Kenya recognize that there are changes in climatic in terms of temperature and rainfall that have taken place in the County over time (Figures 4-6), and that the changes have moderate to high impact on smallholder dairying (Table 5).Secondary data from local meteorological station indicted that Migori County has generally experienced $3^{o}C$ increase in mean minimum day and night temperatures over a 30-year period (1982-2015), and an increase of 195mm in annual rainfall between 1980 and 2013. While respondents' perceptions are in agreement with this, the study respondents noted that the rainfall distribution, seasonality, intensity, and frequency has become erratic and quite unpredictable. These perceptions significantly influenced their adoption of climate change adaptive strategies. In order to cope with the perceived changes in climate, study respondents adapted by practicing mixed farming, semi-intensive dairy production, using household as the main source of farm labour, reducing herd size to 2 dairy cattle, establishing own fodder, rearing cross-bred dairy cattle, and which are mainly of Non-Friesian blood and their crosses, and maintaining an increasing trend in income earnings from milk sales(Figure 7). Of these adaptive strategies, the study established that mixed farming, non-intensive dairy production system, and own fodder were the main factors that determine smallholder dairy farmers' climate change adaptability (Table 6). The study respondents have a statistically significantly high level of local adaptation to climate change effects on the dairy industry($7.05<Z< 17.82$; $p<0.05$) as shown in Table 8.

Respondents' gender and household size have a statistically significant influence on smallholder dairy farmers' adaptation to climate change effects in the study area. Total score and knowledge on how climate change affected forage and water availability, dairy cattle diseases and parasites, milk production, earnings from dairying, dairy cattle's adaptability to local conditions, and farmers' ability to deal with climate change effects were established to significantly influence smallholder dairy farmers' adaptation to climate change effects.The study respondents were also very rich in indigenous knowledge regarding climate change, which was also very useful in aiding their adaptation to climate change. Moreover, study findings indicated that public extension service, radio, and other farmers were the main sources of institutional support; even though television (TV), internet, government research institutions, and public universities also play a critical role. The level of exposure to climate change information has a statistically significant and positive influence on farmers' adaptation to climate change effects.

From the findings, the farmers' high level of climate change adaptation (Table 10) arises from their perceptions of climate changes (with respect to temperature and precipitation), above-average (61%) level of knowledge of climate change effects (Figure 10), the high level of access to climate information (Table 28) from the several sources (mainly public extension, radio and television), and the actual support to enable the farmers adapt to climate change effects (Table 29); all of which significantly influenced their decision to adopt climate change adaptation strategies.

Major barriers to climate change adaptation noted included limited and irregular flow of information on climate change and adaptation, weak research-extension-farmer linkage, inadequate feed and water for dairy cattle, poor access to credit, high costs of farm inputs, poor access to fur-flung parts of the County, poor milk marketing, and lack of county environment action plan.

5.3 Conclusions

From the study findings, it was concluded that climate changes have taken place in Migori County, with moderate to high effects on the performance of the smallholder dairy industry. Migori smallholder dairy farmers, however, have a significantly high level of adaptation to climate change effects, hence; are more likely to increase productivity, sustain production and income from the dairy enterprise. Therefore, the null hypothesis was rejected.

Smallholder dairy farmers' socio-demographic characteristics positively and significantly influence smallholder dairy farmers' adaptation to climate change effects such that, male farmers with large household sizes are more likely to adapt well to climate change effects than their female counterparts with small household sizes. Therefore, the null hypothesis was rejected.

Moreover, smallholder dairy farmers' perceptions of changes in temperature and precipitation significantly and positively influence their adaptive strategies to climate change effects, making them adjust their dairy operations accordingly for sustainable food, nutrition and income security. Therefore, the null hypothesis was rejected.

From the study findings, Migori smallholder dairy farmers have high knowledge of climate change and climate change effects, despite having only basic formal education. This high knowledge is useful in helping them to adapt well to climate change effects, with the above average overall score greatly influencing respondents' climate change adaptive strategies. Thus, knowledgeable farmers are better adapted to climate change effects. Therefore, the study rejected the null hypothesis.

In terms of institutional support, Migori smallholder dairy farmers obtain climate change information from several public and private institutions and agencies; with public extension service, radio and television being the most significant in influencing climate change adaptation. The level of institutional support has a positive and significant influence on farmers' climate change adaptation. The null hypothesis was therefore, rejected.

5.4 Recommendations

From the study findings, it was recommended that for sustainability of local adaptation by smallholder dairy farmers, governments and key partners must provide the much-needed external support in terms of extension and farmer advisory services, policy and institutional framework, and market linkages.

Governments and partners should ensure equity in reaching out to rural smallholder dairy farming households in terms of accessing climate change support to enhance adaptation. In patriarchal societies, in particular, stakeholders should be more intentional in identifying, targeting and supporting female-headed smallholder dairy farming households with small household sizes in their efforts to adapt to climate change effects. Climate smart technologies that recognize the unique needs of such households should be developed and promoted in order to improve smallholder dairy farmers' climate change adaptation.

Moreover, governments should invest more in infrastructure for accurate weather prediction and dissemination, and put in place policies and institutional frameworks to support local adaption by smallholder farmers to climate change effects.

Governments and stakeholders should incorporate smallholder dairy farmers' indigenous knowledge in developing climate change mitigation and adaptation plans, strategies and policies.

Governments should network with other development partners to provide credible and timely climate change advisory services using appropriate channels to improve smallholder dairy farmers' adaptation to climate change effects. More climate change information and adaptation options should be channelled to rural farming communities through mass media, notably; radio and television. Governments, research institutions, universities, NGOs, private society, and donors should collaborate and promote participatory farmer-based extension approaches (e.g. field days, on-farm demonstrations, farmer exchange visits, and ASK shows). These approaches are more cost-effective and enable experiential learning by farmers. Moreover, such approaches would enable researchers, extension agents, policy makers, private players and other stakeholders to interact with farmers and get their feedback for further technology and policy development and refinement.

5.5Take-home message and Intervention logic in improving climate change adaptation in smallholder dairy systems

The study has established that climate change has taken place in Migori County-Kenya between 1980 and 2015, with farmers adopting mixed adaptive strategies for sustainability depending on their socio-demography, perceptions, level of climate change knowledge, and institutional support. Farming type, production method, and fodder source are the main determinants of smallholder dairy farmers' climate change adaptation; with major barriers to climate change adaptation being unreliable weather fore-casting and use of technical language in weather forecasting; inaccessibility to farm inputs; ignorance and high illiteracy levels; limited access climate change information; low government extension staff capacity; and weak research-extension-farmer linkages.

In order to improve climate change adaptation among smallholder dairy farming systems, governments and stakeholders should work together to invest in weather forecasting and ensure that farmers get accurate, reliable and timely access to climate change information; use radio, television and farmer-friendly extension approaches to disseminate climate information; promote equity and particularly support female-headed households with small family sizes in their efforts to adapt to climate change;
incorporate local climate change knowledge in formulating community based climate change plans, strategies and policies.

5.6Areas for further research

Further studies should be undertaken in the following areas:

I. The key drivers of smallholder dairy farmers' perceptions of and adaptability to climate change effects; whether social, cultural, economic, political, educational, or technological factors;

II. The interaction between socio-demographic factors and farmers' perceptions in determining adaptation to climate change effects;

III. The interaction between knowledge and perception in determining smallholder dairy farmers' adaptation to climate change effects;

IV. The interaction between knowledge and institutional support in determining smallholder dairy farmers' adaptation to climate change effects.

V. An understanding of whether social, cultural, economic, political, educational, or technological factors have a bearing on smallholder dairy farmers' perceptions and adaption to climate change effects.

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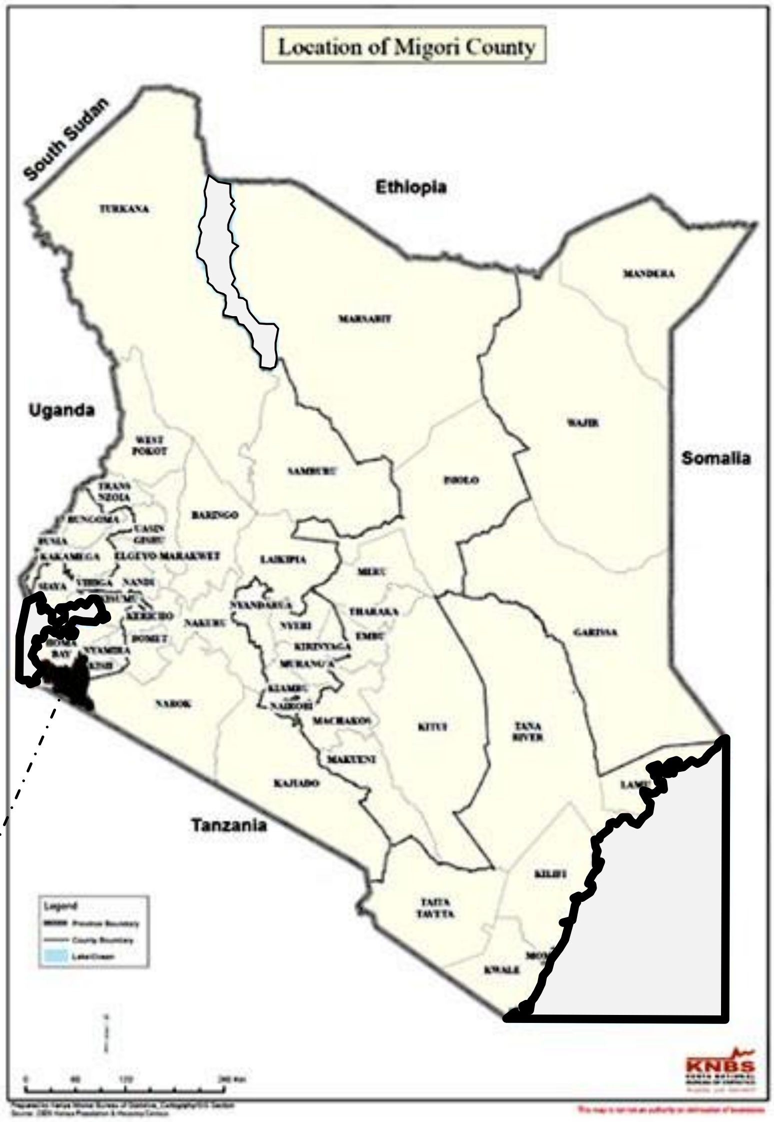
APPENDICES

APPENDIX I: LIST OF PUBLICATIONS FROM THE STUDY

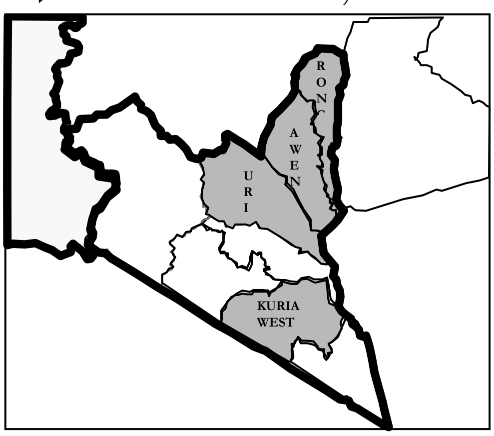
Odhiambo, C.O., Ogindo, H.O., Wasike, C.B. & Ochola, W.O. (2019). Adaptation of Smallholder Dairy Farmers in South Western Kenya to the Effects of Climate Change. *Journal of Atmospheric and Climate Sciences,* Vol.9, No. 3, pp. 456-478 (July, 2019). http://www.scirp.org/journals/acs. ISSN Online: 2160-0422; ISSN Print: 2160-0414.

Odhiambo, C.O., Ogindo, H.O., Wasike, C.B. & Ochola, W.O. (2019). Effect of Socio-Demographic Charcteristics on Kenyan Smallholder Dairy Farmers' Adaptive Strategies to Climate Change Effects. *Journal of Atmospheric and Climate Sciences*, Vol. 9, No. 4, pp.583-599 (October, 2019). http://www.scirp.org/journals/acs. ISSN Online: 2160-0422; ISSN Print: 2160-0414.

APPENDIX II: MAP OF THE STUDY AREA



Sub-counties of study (Rongo, Awendo, Uriri and Kuria West)



APPENDIX III: QUESTIONNAIRE FOR SMALLHOLDER DAIRY FARMERS

DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA

SURVEY QUESTIONNAIRE

AEZ:____Sub-County:_____________Ward:________________Location:______________

Sub-location:__________________________Village:_______________________

HH No.:______________S/No.:_________________Interviewer:_____________________

Interview Date:_____________ Interview start:____________Interview end:____________

Informed Consent Page

Your household is among those randomly selected from this Village to participate in this study. We would like to find out some information about climate change and dairy farming that you undertake. The information will be useful in helping to improve smallholder dairy famers' level of understanding, preparedness and coping strategies to climate change effects so as to remain in production; make profits and make significant contributions to Kenya's economic growth and development.

Participation in this study is purely voluntary, and we can only promise that we shall share with you and others the study findings. If you agree, we will ask you some questions regarding the above-mentioned aspects. We will try our best to keep the information you give us very confidential. We will not tell anyone you took part in this study. Your name will not be written down. You don't have to answer any questions if you don't want to, and you are free to withdraw from the study at any time should you find that you are unable to continue. No one will be upset with you.

Do you agree to take part? ***(Please tick)*** □ Yes □ No

Note: Only proceed with the interview if the respondent consents

Name of Respondent:____________________________I.D. Number:_____________

Telephone:____________________Sign:____________________Date:____________

SECTION A: SOCIO-DEMOGRAPHIC CHARACTERISTICS OF HOUSEHOLD

1. Sex of respondent***(Tick)***

1	**Male**		**2**	**Female**	

2. How old are you? ____________________________***(Please indicate date of Birth)***

3. What is your marital status? ***(Tick)***

1	**Single**		**3**	**Divorced**	
2	**Married**		**4**	**Separated**	
5	**Widow**		**6**	**Widower**	
66	**Other (Specify)**				

4. What is your highest level of formal education? ***(Tick)***

0	**Never went to school**		**1**	**Completed Lower Primary Education (Class 1-3)**	
2	**Did not complete Upper Primary education**		**3**	**Completed Primary Education**	
4	**Did not complete Secondary education**		**5**	**Completed Secondary education**	
6	**Completed Polytechnic after Pri. Education**		**7**	**Completed Polytechnic after Sec. Education**	
8	**Completed Informal/Adult Education**		**9**	**Completed Certificate Level of education**	
10	**Completed Diploma Level of education**		**11**	**Completed First Degree**	
12	**Post-graduate Degree**		**99**	**Other (Specify)**	

5. How many people have been living in this house, cooking and eating together from the same pot over the past six months?__________***(please probe to establish the correct household size)***

6. What is your level of experience (in years) in dairy farming?__________***(Please indicate year when respondent begun practicing dairying to establish correct level of experience)***

7. What is your total area of land in acres?________________________acres

8. How much is your household's total monthly income (from all sources) in Kshs.?_____________________

SECTION B: PERCEPTION OF CLIMATE CHANGES IN MIGORI COUNTY

Comparing the climate of this community now and the past fifteen years, what changes would you say have taken place regarding the following parameters of climate? **(Please probe to establish the correct position)**

9. What observable/noticeable changes in day temperatures would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

    1. Experienced a rise [ ]   2. Experienced no change [ ]
    2. Experienced a decrease [ ]

10. What observable/noticeable changes in night temperatures would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

    1. Experienced a rise [ ]   2. Experienced no change [ ]
    3. Experienced a decrease [ ]

11. What observable/noticeable changes in rainfall seasons would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

    1. Seasons have increased [ ]   2. Seasons have remained the same [ ]
    3. Seasons have reduced [ ] 4. We have rains throughout the year [ ]

12. What observable/noticeable changes in rainfall amounts for the short rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

    1. Amounts have increased [ ]   2. Amounts have remained the same [ ]
    3. Amounts have reduced [ ]

13. What observable/noticeable changes in rainfall amounts for the long rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

    1. Amounts have increased [ ]   2. Amounts have remained the same [ ]
    3. Amounts have reduced [ ]

14. What observable/noticeable changes in onset of rainfall for the short rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Onset nowadays delays [ ] **2. Onset comes earlier than fifteen years ago [ ]**
3. Onset is very unpredictable [ ]

15. What observable/noticeable changes in onset of rainfall for the long rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Onset nowadays delays [ ] **2. Onset comes earlier than fifteen years ago [ ]**
3. Onset is very unpredictable [ ]

16. What observable/noticeable changes in duration of rainfall (total length)for short rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Duration has reduced [ ] **2. Duration has remained the same [ ]**
3. Duration has increased [ ]

17. What observable/noticeable changes in duration of rainfall (total length) for long rainy season would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Duration has reduced [ ] **2. Duration has remained the same [ ]**
3. Duration has increased [ ]

18. What would you say of the period taken during a single raining episode during the short rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is shorter [ ] **2. Has not changed [ ]** **3. Is longer [ ]**

19. What would you say of the period taken during a single raining episode during the long rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is shorter [ ] **2. Has not changed [ ]** **3. Is longer [ ]**

20. What would you say of the distribution (spread/area covered by rainfall) during the short rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is better [ ] **2. Has not changed [ ]** **3. Is worse [ ]**

21. What would you say of the distribution (spread/area covered by rainfall) during the long rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is better [ ] 2. Has not changed [ ] 3. Is worse [ ]

22. What would you say of the distribution (spread/area covered by rainfall) during any single rainy episode during the short rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is better [ ] 2. Has not changed [ ] 3. Is worse [ ]

23. What would you say of the distribution (spread/area covered by rainfall) during any single rainy episode during the long rainy season in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Is better [ ] 2. Has not changed [ ] 3. Is worse [ ]

24. What observable/noticeable changes in intensity of rainfall (strength) for the short rains would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Intensity has reduced [ ] 2. Intensity has remained the same [ ]
3. Intensity has increased [ ]

25. What observable/noticeable changes in intensity of rainfall (strength) for the long rains would you say have taken place in your community comparing now and fifteen years ago?**(Please probe to tick correct response given)**

1. Intensity has reduced [ ] 2. Intensity has remained the same [ ]
3. Intensity has increased [ ]

26. What observable/noticeable changes in intensity of rainfall (strength) during any single rainy episode for the short rains would you say have taken place in your community comparing now and fifteen years ago?

1. Intensity has reduced [ ] 2. Intensity has remained the same [ ]
3. Intensity has increased [ ]

27. What observable/noticeable changes in intensity of rainfall (strength) during any single rainy episode for the long rains would you say have taken place in your community comparing now and fifteen years ago?

1. Intensity has reduced [ ] 2. Intensity has remained the same [ ]
3. Intensity has increased [ ]

SECTION C: KNOWLEDGE OF CLIMATE CHANGE EFFCETS ON SMALLHOLDER DAIRY INDUSTRY IN MIGORI COUNTY

For each of the following set of questions, kindly respond by stating **"Yes"** or **"No",** based on your understanding of the changes in climate that have taken place in this community over the past fifteen years, and your experience in dairy farming.***(Please use the score guide provided to award 1 for all correct responses given and 0 for all incorrect responses given):***

28. Because of changes in climate, some forages (shrubs and herbs) that dairy cattle used to take as feeds have disappeared from the community.

1	**Yes**	
2	**No**	

Score:___

29. Because of changes in climate, new types of forages (shrubs and herbs) have emerged, some of which are poisonous to dairy cattle in this community.

1	**Yes**	
2	**No**	

Score:___

30. Because of changes in climate, it is nowadays more difficult to control common pests/parasites like ticks affecting dairy cattle using the conventional chemicals (acaricides) alone.

1	**Yes**	
2	**No**	

Score:___

31. Because of changes in climate, diseases that used to be easy to manage are becoming very complicated, often leading to death of dairy cattle in this community.

1	**Yes**	
2	**No**	

Score:___

32. Because of changes in climate, milk produced by dairy cattle has somehow gone down in this community.

1	**Yes**	
2	**No**	

Score:___

33. Because of changes in climate, available water and its quality for dairy cattle in this community has changed.

1	**Yes**	
2	**No**	

Score:___

34. Because of changes in climate, the breeds of dairy cattle that used to live well and produce well (i.e. adaptable) to the environment in this community no longer live well and do well.

1	**Yes**	
2	**No**	

***Score:*___**

35. Changes in climate have not had any significant effect on the number and types (variety) of forges (shrubs and herbs) available for dairy cattle in this community.

1	**Yes**	
2	**No**	

***Score:*___**

36. Changes in climate have not had any significant effect on the water (amounts and quality) available for dairy cattle in this community.

1	**Yes**	
2	**No**	

***Score:*___**

37. Changes in climate have not had any significant effect on the number and types of parasites affecting dairy cattle in this community.

1	**Yes**	
2	**No**	

***Score:*___**

38. Changes in climate have not had any significant effect on the number and types of diseases affecting dairy cattle in thus community.

1	**Yes**	
2	**No**	

***Score:*___**

39. Changes in climate have not had any significant effect on milk produced from dairy cattle in this community.

1	**Yes**	
2	**No**	

***Score:*___**

40. Despite changes in climate, the income earned by dairy cattle farmers in this community from milk sales has not changed much.

1	**Yes**	
2	**No**	

***Score:*___**

41. Despite changes in climate, dairy cattle have continued to be well adaptable to living in the environment in this community.

1	**Yes**	
2	**No**	

***Score:*___**

42. Dairy cattle farmers of this community cannot deal with effects of changes in the climate that affects their dairy enterprise.

1	**Yes**	
2	**No**	

***Score:*___**

Researcher's Section: Total Score_____/15=_____%

SECTION D: SOURCES AND TYPES OF INSTITUTIONAL SUPPORT

43. From where do you get information regarding climate change that has been useful to you as a smallholder dairy farmer?***(Please list)***

Code	*Source of information regarding climate change and how to adapt as a smallholder dairy farmer*	*Type of institutional support (To be filled by Researcher)*

Key		
Code	***Source of information***	***Type of source of information***
1.	Government extension agents	Extension personnel
2.	Private extension agents	Extension personnel
3.	Government research institutions	Research institution
4.	Public universities	University
5.	Private universities	University
6.	Other farmers	Other farmers
7.	Radio set	Electronic and print media
8.	Television set	Electronic and print media
9.	Newspapers and pamphlets	Electronic and print media
10.	Internet	Electronic and print media

44. Which of these are your three most important sources of information regarding climate change and its effect on smallholder dairy farming in your community?(***Please rank in order of priority).***

Rank	**Source of information regarding climate change**	**Code for source of information regarding climate change**	**Type of source of information*(To be filled by Researcher)***
1.			
2.			
3.			

45. Comment on your level of satisfaction with the information you get from your most preferred source regarding climate change and its effect on dairy farming in your community.

1	2
Satisfied	***Not Satisfied***

46. What would you do to improve the usefulness of the information you get regarding climate change and its effect on dairy farming?

1	2
Improve access	***Consult more***

SECTION E: ADAPTIVE STRATEGIES TO EFFCETS OF CLIMATE CHANGE

47. What problems do you face as a smallholder dairy farmer in an effort to adapt to effects of climate changes that have occurred in your community?***(Tick all that are mentioned).***

Code	Climate Change Effect	Low effect (1)	Moderate effect (2)	High effect (3)
1	Pasture loss			
2	Drying of nearest water sources			
3	Loss of livestock			
4	Under feeding of livestock			
5	Increase in diseases and pests			
6	Selling of livestock at throw away prices			
7	Long walk in search of water and pasture			
8	Over grazing of land			
9	Poor market for the livestock products due to poor quality			
10	More human labour required			
11	Increase in livestock-human –wildlife conflicts			
12	Reduced milk production			
13	Water scarcity			

48. What type of farming do you practice in your smallholder dairy farm?***(Tick as appropriate)***

1	0
Mixed crop and dairy farming	***Pure dairy farming***

49. Considering the effects of climate change in your area, why do you prefer the type of farming you practice?***(Tick all that are mentioned)***.

Cod e	Reason for preferring production method	Yes (1)	No (2)
1	Helps to spread risk/reduces risk of total loss		
2	Allows for complementarity of enterprises (enterprises benefit from one another)		
3	Reduces overall cost of production		
4	Assures sustainability in business		
5	Increases household income		
6	Allows for gathering information about farming from several different sources		
7	Easy to market produce		

50. What production method do you employ in your dairy farm?

1	0
Non-intensive dairy farming*(includes all methods where zero grazing is integrated with tethering and/or free range)*	***Intensive dairy farming*** *(i.e. pure zero-grazing)*

51. Considering the effects of climate change in your area, why do you prefer the production method that you have adopted in your farm?***(Tick all that are mentioned)***.

Code	Reason for preferring production method	Yes (1)	No (2)
1	Reduces labour demand		
2	Gives flexibility to engage in other activities		
3	Allows for efficient utilization of scarce feed resources		
4	Reduces cost of parasite and disease control in the farm		
5	Reduces chances of theft of dairy cattle		
6	Reduces cost of watering the animals		
7	Allows for utilization of farm by-products		
8	Allows for close monitoring of all groups of dairy animals in farm		

52. Which is your main source of fodder for the dairy cattle that you keep?

1	0
Own farm *(includes both green and dry/preserved fodder obtained from farmer's own farm)*	***Not from own farm*** *(includes green and dry/preserved fodder from elsewhere, and includes concentrates from Agrovets)*

53. Considering the climate change effects in your area, are you satisfied with your current sources of feeds for your dairy cattle? **1. Satisfied [ ]** **2. Not Satisfied [ ]**

54. Which types of breeds of dairy cows do you keep in your farm? ***(Please observe and tick appropriately).***

1	0
Non Pure breed *(i.e. Cross breeds)*	***Pure breeds***

55. Considering the effects of climate change in your area, why do you prefer to keep the type of breeds you have in your farm?***(Tick all that are mentioned)***.

Code	Reason for preferring production method	Yes (1)	No (2)
1	They are more adaptable to the local climate		
2	They are more parasite-and disease-tolerant		
3	They have a comparatively lower feed and water demand		

4	They are high yielding
5	They mature fast and come into production early
6	They have high twinning ability
7	They have comparatively low labour demand
8	Allows for close monitoring of all groups of dairy animals in farm
9	They are more affordable

56. Which breeds of dairy cattle do you keep in your farm?***(Please observe and tick appropriately).***

1	0
Ayrshires, Guernseys, Jerseys and/or their crosses	***Friesians and their crosses***

57. Considering the effects of climate change in your area, why do you prefer to keep these breeds of dairy cows in your farm?***(Tick all reasons given).***

Code	Reason for preference	Yes (1)	No (2)
1	High milk production		
2	High butterfat content		
3	Adaptability to local climatic conditions		
4	Adaptability to common diseases and parasites		
5	Low feed requirements		
6	Low water requirements		
7	Early maturing (Comes into calving early)		
8	High twinning ability		
9	Affordability of the animal		

58. How many dairy cows do you keep?***(List total number)*_______**

1. Two and above [ ]0. Less than two [ ]

59. Considering the effects of climate change in your area, why do you prefer to keep this number of dairy cows in your farm?***(Tick all reasons given).***

Code	Reason for preference	Yes (1)	No (2)
1	Easy to manage		
2	Gives high returns per unit area		
3	Have less labour requirement		
4	Commensurate to the feed resources available in my farm		
5	Commensurate with my animal health management level/kills		

6	Commensurate with my animal housing management level/skills
7	Commensurate with my animal fertility management level/skills
8	Advised by extension agents to keep that number
9	Affordability of the animals
10	High returns when animal is sold

60. Which is your main source of farm labour for the dairy farm?

1	0
Household labour *(includes self and other household members)*	***Non Household labour*** *(includes permanently hired and casual labour)*

61. What would you say of your level of satisfaction with your sources of farm labour considering the effects of climate change in your area?

1	2
Satisfied	***Not Satisfied***

62. What plans do you have to improve on the sufficiency of your farm labour so as to increase the productivity of your farm, considering the climate change effects in your area? ***(Please tick all that are mentioned)***

Code	Plan to improve sufficiency of farm labour	Yes (1)	No (2)
1	Hire at peak times		
2	Mechanize production		
3	Supplement with labour from neighbours when schools are closed		
4	Supplement with labour from friends/group of friends at peak times		
5	Supplement with labour from visiting relatives		
6	Supplement with labour from school children (especially over week-ends) in need of pocket money		
7	Reduce number of farm animals		
8	Sell all bull calves to ensure only heifers and cows remain in farm		

63. What has been the trend in your level of income from dairy farming over the past ten (10) years?

1. Increased [ ] **2. Remained same [ ]** **3. Declined [ ]**

64. Considering the effects of climate change in your area, how satisfied are you with your monthly income from the sale of milk from your dairy cattle?

1. Satisfied [ ] **2. Not Satisfied [ ]**

65. Considering the effects of climate change in your area, what would you do to improve the monthly income from dairy enterprise in your farm?***(Tick all that are mentioned).***

Code	Measures to improve monthly income from dairy enterprise	Yes (1)	No (2)
1	Keeping more dairy goats than cows		
2	Going for high yielding breeds of dairy cattle		
3	Going for more crosses of zebu and exotic breeds		
4	Increasing level of intensification (adopting more zero-grazing practices)		
5	Hiring more land for establishment of pasture and other feeds		
6	Buying more land for establishment of pasture and other feeds		
7	Increasing number of exotic breeds in the farm		
8	Improving on management of diseases and parasites in the farm		
9	Improving water source		
10	Improving on fertility management		
11	Improving on housing of dairy cattle in the farm		

Thank you for your participation in this study

APPENDIX IV:KEY INFORMANT INTERVIEW GUIDE FOR HEADS OF GOK, RESEARCH & PARASTATAL UNITS

DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA

KEY INFORMANT INTERVIEW GUIDE FOR HEADS OF GOVERNMENT (MoALF, MENR & COOPERATIVES), RESEARCH (KALRO) & PARASTATAL UNITS (LBDA, NEMA, & METEOROLOGY)

Informed Consent Page

The principal focus of this discussion is to get your understanding and views regarding climate change and smallholder dairy farming activities in this County.

The information you shall provide will be useful in helping improve smallholder dairy famers' level of understanding, preparedness and coping strategies to climate change effects so as to remain in production; make profits and make significant contributions to Kenya's economic growth and development.

The information you will provide will be treated with utmost confidentiality, and the final report will not bear your name, but only your views, alongside those of others. Participation in this study is purely voluntary, and you are free to withdraw at any point should you find you are unable to continue.

Are you willing to participate in this discussion? Yes [ ] No [ ]

Respondent's Name:___________________________________Designation:____________________

I.D. Number:_____________________Telephone No.:______________________________

Signature:________________________________Date:___________________________

Note: If the respondent declines the interview, thank them for their time and proceed to the next respondent.

Key Informant's Name	
Position/Role	
Office	
Location (Duty Station)	
Place of Interview	
Name of Interviewer	
Name of Note-taker	
Date of Interview	

Interview started:________________________Interview ended:_______________

INTRUCTIONS

- **Introduce yourself and explain the purpose of the study.**
- **Use the questions only as a guide and probe further where necessary.**
- **Seek as much information as possible.**
- **Explain the purpose of voice recorder, and only take note of cues that could remind you of key responses given.**
- **Be involved in the interview and take note of non-verbal communication.**

<u>Interview questions</u>

A. Perception of Climate change in Migori County with respect to temperature

1. Comparing the **temperatures** of Migori County now with those fifteen years ago, what changes would you say have taken place regarding **day** and **night** temperatures? *(Probe for evidenced change)*

B. Perception of Climate change in Migori County with respect to precipitation

2. Comparing the rainfall of Migori County now with that experienced fifteen years ago, what changes would you say have taken place? *(Probe for changes in rainfall seasons, amounts, intensity, distribution, predictability in the onset, and total duration**)***

C. Impact of Climate Change on smallholder dairy industry of Migori County and farmers' adaptive strategies

3. How have the changes you have mentioned with respect to temperatures and rainfall affected smallholder dairy farmers of Migori County and how have they responded to the effects in order to remain in business? *(Probe for effect in terms of type of farming practiced, level of intensification of the dairy enterprise, type and choice of breeds of dairy cattle kept, herd dynamics, number of dairy cattle kept, housing for dairy cattle, feeds and feeding of dairy cattle, diseases and parasites affecting dairy cattle, fertility and reproduction of dairy cattle, watering of the dairy cattle, labour type and availability, level of capital investment in dairy enterprise, and milk production and income from milk sales)*

Effect	*Response/adaptation by smallholder dairy farmers*

4. What are the **challenges** (difficulties) facing smallholder dairy farmers of Migori County as they try to adapt to the effects of climate change taking place in this area?

D. Sources of Information on Climate change and climate change effects to smallholder dairy farmers of Migori County

5. a) From where do the smallholder dairy farmers of Migori County get information regarding climate change and climate change effects?
   b) Rank the sources of information you have mentioned above (At least the three most important sources).

c) Are there gaps in terms of information flow to the smallholder dairy farmers of Migori County regarding climate change and climate change effects?

d) What could be done to improve on the flow of information reaching the smallholder dairy farmers of Migori County concerning climate change and climate change effects?

E. Sources and types of institutional support to smallholder dairy farmers of Migori County

6. a) Mention the individuals, institutions, and/or groups (Including government, research or academic institutions if any) and the type of support each of them provides to smallholder dairy farmers of Migori County to better adapt to the effects of climate change.

Individuals/Institutions/groups supporting smallholder dairy farmers of Migori County to better adapt to climate change effects	*Type of support provided*

7. Which areas still need support, and which entity/institution is better placed to provide that?

Area of gap	*Institution better placed to provide support/mitigate gap*

F. Measures to improve Migori County's smallholder dairy farmers' adaptation to climate change effects

8. Based on your knowledge of climate change, mention what the smallholder dairy farmers of Migori County are currently doing, but **should stop doing** in order to sustainably adapt to the effects of climate change.

9. Based on your knowledge of climate change, mention what the smallholder dairy farmers of Migori County **are already doing**, and **should continue doing/could do differently** in order to sustainably adapt to the effects of climate change.

10. Based on your knowledge of climate change, mention what the smallholder dairy farmers of Migori County are **currently not doing,, but should start doing**, which could enable them to adapt better to the effects of climate change.

Thank you for participation in this study!

APPENDIX V:FOCUS GROUP DISCUSSION GUIDE

DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA

FOCUS GROUP DISCUSSION GUIDE FOR FARMER GROUPS, DAIRY COOPERATIVE SOCIETIES AND ENVIRONMENTAL CONSERVATION GROUPS

Name of group	
Major Group Activity	
Name of Sub-county	
Name of Ward	
Name of Location	
Name of Sub-location	
Name of Village	
Group members present (Females & Males)	
Name of Facilitator/Moderator	
Name of Note take/recorder	
Venue of meeting	
Date	

Discussion begins: __________________________Discussion ends:______________________________

As participants arrive thank them warmly for coming, welcome them and put them at ease by friendly conversation. [When the group is complete] Introduce yourself and the note taker and state the use of the voice recorder. Reaffirm from the members that they have come voluntarily to participate in the discussion and that they can still withdraw from the group if they wished to. Seek this consent by a show of hands.

INTRODUCE TOPIC OF DISCUSSION:

The principal focus of this discussion is to get your understanding and views regarding climate change and smallholder dairy farming activities in your community.

The information will be useful in helping improve smallholder dairy famers' level of understanding, preparedness and coping strategies to climate change effects so as to remain in production; make profits and make significant contributions to Kenya's economic growth and development.

The information you will provide will be treated with confidentiality, and the final report will not bear your name, but only your views. Participation in this study is purely voluntary, and you are free to withdraw at any point should you find you are unable to continue.

Ask the group if it is willing to participate in the study. Let it be shown by acclamation.

Group is willing to participate in the study (Tick as appropriate): Yes [ ] No [ ]

Note: If the response is No, please move to the next group.

AGREE ON NORMS AND CONFIDENTIALITY

- Explain the session shall be in form of a discussion
- Stress that there are no right or wrong answers
- Ask participants to feel free to say what they think
- Ask the group to treat what others say as confidential
- Agree on use of cell phone and leaving the room while discussion is in progress etc.
- Tell the discussants how long the discussion will take.

Remind participants this is voluntary and they are free to leave at the start or any time during the discussion.

Discussion questions

A. Perception of Climate change with respect to temperature

1. Comparing now and fifteen years ago, what **changes** would you say have taken place in **day and nighttemperatures** over this area? *(Probe for evidences of noticeable change)*

B. Perception to Climate change with respect to precipitation

2. Comparing now and fifteen years ago, what **changes** have taken place in **rainfall** over this area? (*Probe for changes in rainfall seasons, amounts, intensity, distribution, predictability in onset, and total duration).*

C. Sources of information on climate change and climate change effects

3. a) From where do the smallholder dairy farmers in your community get **information** regarding **climate change** and **climate change effects**?

b) Rank the sources of information you have mentioned above (At least the three most important sources).

c) What **gaps** exist in terms of **information flow** to the smallholder dairy farmers of your community regarding climate change and climate change effects and how could these be mitigated?

D. Understanding Climate Change effects on Smallholder Dairy Production and adaptation

4. What have been the implications of the observed changes in climate in this area for smallholder dairy farmers, and how have they tried to adapt? (*Probe for implications in terms of survival to maturity of dairy cattle, total quantities and quality of water available for dairy cattle, total amount and variety (type) of feeds (shrubs and herbs) available for dairy cattle, number and types (variety) of diseases and parasites of dairy cattle, fertility and productivity (in terms of calving) of dairy cattle, housing requirements, and milk production and income from milk sales)*

5. What **challenges** (difficulties) do smallholder dairy farmers in your community face as they try to adapt to the effects of climate changes in this area?

6. Suggest **what else could be done** by smallholder dairy farmers in this community to **better adapt** to the effects of changes in climate taking place in this area.

E. Institutional support to smallholder dairy farmers

7. a) Who are the **individuals, institutions, and/or groups** (Including government, research or academic institutions if any) **supporting smallholder dairy farmers** of your community to **better adapt** to the effects of climate change, and what support do they provide?

Individuals/Institutions/Groups supporting smallholder dairy farmers to adapt to climate change effects	*Support provided*

b) What **gaps** still to be addressed for improved adaptation by smallholder dairy farmers of this community, and who is better placed to address them and how? Please mention any that you know of?

Gaps for better adaptation to climate change effects	*Individuals/Institutions/Groups better placed to address them and how*

Thank you for participation in this study!

APPENDIX VI:FOCUS GROUP DISCUSSION GUIDE FOR ELDERS

DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA

FOCUS GROUP DISCUSSION GUIDE FOR ELDERS (Over 60 Years)

Sub-County:	
Location:	
Sub-Location/Ward	
Village:	
Discussion Venue:	
Group Name (if applicable):	
FGD Participants Present (Total):	
Female:	
Male:	
Facilitator/Moderator:	
Note taker/Recorder:	
Observer:	
Date:	
Time Discussion Started:	
Time Discussion Ended:	

As participants arrive thank them warmly for coming, welcome them and put them at ease by friendly conversation. [When the group is complete] Introduce yourself and the note taker and state the use of the tape recorder. Reaffirm from the members that they have come voluntarily to participate in the discussion and that they can still withdraw from the group if they wished to. Seek this consent by a show of hands.

INTRODUCE TOPIC OF DISCUSSION:

We are here to find out what changes in climate have occurred in your area, how those changes have affected smallholder dairy farmers in your community, and what is being done to remain in business (produce milk and satisfy the demand).

The information will be used to prepare general reports, but will not include any specific names. We can only promise that we shall share our findings with stakeholders in the dairy industry in this County and produce publishable materials that will be read by other people outside this County and this Nation. Participation in the discussion is voluntary and the information you provide will be treated with confidentiality. You are free to withdraw from the study at any point should you find you are unable to continue. For purposes of quality assurance of the information, we request that you allow us to use ***voice recording*** *of this discussion.*

Are you willing to participate in this discussion? Yes [ ] No [ ]

Note: If the response is No, please move to the next group.

AGREE ON NORMS AND CONFIDENTIALITY

- Explain the session shall be in form of a discussion
- Stress that there are no right or wrong answers
- Ask participants to feel free to say what they think
- Ask the group to treat what others say as confidential
- Cell phone use and leaving the room while discussion is in progress etc.
- Tell the discussants how long the discussion will take.

Discussion questions

A. Perception of Climate change with respect to temperatures

1. Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place in your community (between **1980, 1990, 2000, 2010** and **now**) regarding the **day** and **night** temperatures.

B. Perception to Climate change with respect to rainfall

2. a) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place in your community (between **1980, 1990, 2000, 2010** and **now**) regarding the following **rainfall amounts** for both the **long** and **short** rainy seasons.

   b) Discuss the other changes that have taken place in rainfall regarding seasons, intensity, distribution, predictability in onset and total distribution in the past twenty years in Migori County.

C. Understanding Climate Change effects on Smallholder Dairy Production

3. a) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place (between **1980, 1990, 2000, 2010** and **now**) regarding the **total quantities and quality of water available** for dairy cattle in this community.

   b) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place (between **1980, 1990, 2000, 2010** and **now**) regarding the **total amount of milk produced from smallholder dairy enterprise** in this community.

   c) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place (between **1980, 1990, 2000, 2010** and **now**) regarding the **average total monthly income from milk sales from smallholder dairy enterprise** in this community.

   d) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place (between **1980, 1990, 2000, 2010** and **now**) regarding the **total amount and variety of feeds (shrubs and herbs) available** for dairy cattle in this community.

   e) Using appropriate naturally obtained items (stones, leaves, flowers or twigs), depict on the ground, the changes that have taken place (between **1980, 1990, 2000, 2010** and **now**) regarding the **number and types (variety) of diseases and parasites affecting dairy cattle** in this community.

   f) Discuss the changes that have occurred in the past twenty years regarding the **survival to maturity of dairy cattle, fertility and productivity (in terms of calving) of the dairy cattle, and housing requirements for dairy cattle** in this community?

D. Adapting to Climate Change Effects

4. How have **smallholder dairy farmers** of this community **tried to adapt** to (i.e. do things differently in response to) the effects of climate change that have taken place in this area over the past fifteen years in order to remain in production? Please explain.

5. What are the **challenges (difficulties)** facing smallholder dairy farmers in your community as they try to adapt to the effects of climate changes in this area?

6. Suggest **what else could be done** by smallholder dairy farmers, the government and other stakeholders to make smallholder dairy farmers of this community **better adapt** to the effects of changes in climate taking place in this area.

Thank you for participation in this study!

APPENDIX VII:OBSERVATION GUIDE

DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA

OBSERVATION GUIDE

AEZ:_____________Sub-County:________________Location:_______________________

S/Location/Ward:____________________________Village:__________________________

A.	Socio-demographics				
1.	What is the gender of majority of the HH heads of smallholder dairy farmers in the area? (Please tick)			M	F
2.	Who are the majority of HH heads of smallholder dairy farmers in the area? (Please tick)	Youth (18-35 Yrs.)	Middle aged (36-45 Yrs.)	Old (Above 46 Yrs.)	
B.	Observed impact of climate change in the area and efforts to mitigate				
3.	Record observed environmental impacts of climate change in the area at the time of conducting the study (e.g. formation of gullies/ridges, dry river beds, flood basins, conditions of fodder/others) [Please make brief notes about what you observe about each category of impact]	Gullies/ridges	Dry river beds	Flood basins	Condition of fodder/others
4.	Is the community making any efforts to mitigate these observed				

	impacts [Clearly state all observed community efforts to mitigate each impact]				
C.	Observed farming practices, rearing methods, type and numbers of dairy cattle kept				
5.	What farming practices are generally adopted by majority of smallholder dairy farmers in the study area? (Please tick)			Pure dairying	Mixed farming
6.	What rearing method is broadly adopted by smallholder dairy farmers of the study area? (Please tick)		Intensive	Semi-intensive	Free-range
7.	What types of dairy cattle are generally kept by smallholder dairy farmers of the study area? (Please tick)		Pure dairy	Crosses	Mixture of pure dairy & crosses
8.	Which breed is predominant among smallholder dairy farmers in the study area?		Friesians and their crosses	Ayrshires and their crosses	Others (specify)
9.	What is the approximate average number of dairy cattle kept by smallholder dairy farmers of the study area? (Please indicate number)				Number
D.	Sources of Institutional Support				
10.	How do majority of smallholder dairy farmers in the study area acquire information relevant to their business? (Please tick)	Newspapers & reports	Other farmers	Radio	Extension staff/Researchers
E.	Farm labour				
11.	Who are the gender category that provide farm-labour for smallholder dairy farmers in the area?(Please tick)			M	F
12.	What is the general age set of the most predominantly used farm labour in the area? (Please tick)		Children	Youth	Adults
F.	Others				
13.	Record any other striking observation that may be relevant to the study.				

APPENDIX VIII:CHECKLIST FOR COLLECTING SECONDARY DATA DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA

DOCUMENT REVIEW CHECKLIST

A. Meteorological Department Desk Review-Key questions

1. Assess the available documents for **evidence** of **climate change** in Migori County and its environs over the past **30 years***(Precipitation and Temperature data, both temporal and spatial).*

2. Seek to have a **documentary** understanding of how the evidenced **climate changes** would **manifest***(whether in increased droughts, increased precipitation accompanied by flooding, lightning and thunderstorms, windstorms, landslides, etc.)*

3. Seek for **documentaryexplanation** for the observed **climate change** [whether changes in pressure belts over some water bodies, hence; wind patterns, global warming, etc.] *(Emphasis on documentary explanation, not verbal, quote source, author and year).*

4. Seek for a **documentaryunderstanding** of the expected **effects** of the observed climate change on the **environment, infrastructure, plants, livestock, livelihoods** and **human lives** (*Emphasis on documentary understanding, not verbal, quote source, author and year).*

B. **Ministry of Environment & Natural Resources/NEMA Desk Review-Key questions** *(To be compared with findings from the Ministry of Agriculture, Livestock & Fisheries)*

1. Assess available documents for **trends** in **flooding** and/or **drought** in Migori County and its environs over the **past 30 years***(Documentary evidence, quoting source, author, and date).*

2. Assess available documents for **effects** of the observed **floods** and/or **drought** in Migori County and its environs on the **environment, infrastructure, plants, livestock**, **livelihoods** and **humans** *(Documentary evidence, quoting source, author, and date).*

3. Establish **evidenced quantification** of the **effects** of observed **floods** and/or **drought** in Migori County and its environs on the **environment, infrastructure, plants, livestock, livelihoods** and **humans***(Documentary evidence, quoting source, author, and date; Seek for numbers of livestock/humans lost; acres of crops and livestock feeds destroyed; kilometres of road/water connectivity destroyed; value (in Kshs.) of crop yield lost, etc.)*

4. Assess **human response** to the **losses** as a result of **floods** and/or **drought** in Migori County and its environs *(Seek to have a documentary understanding of how the locals responded; what external support they received and from who; how timely the support received was; and the result of the external support).*

5. Assess **gaps** in **dealing** with the observed **effects of climate change** (manifesting in floods and/or droughts etc.) in Migori County and its environs *(Documentary evidence, quoting source, author, and date).*

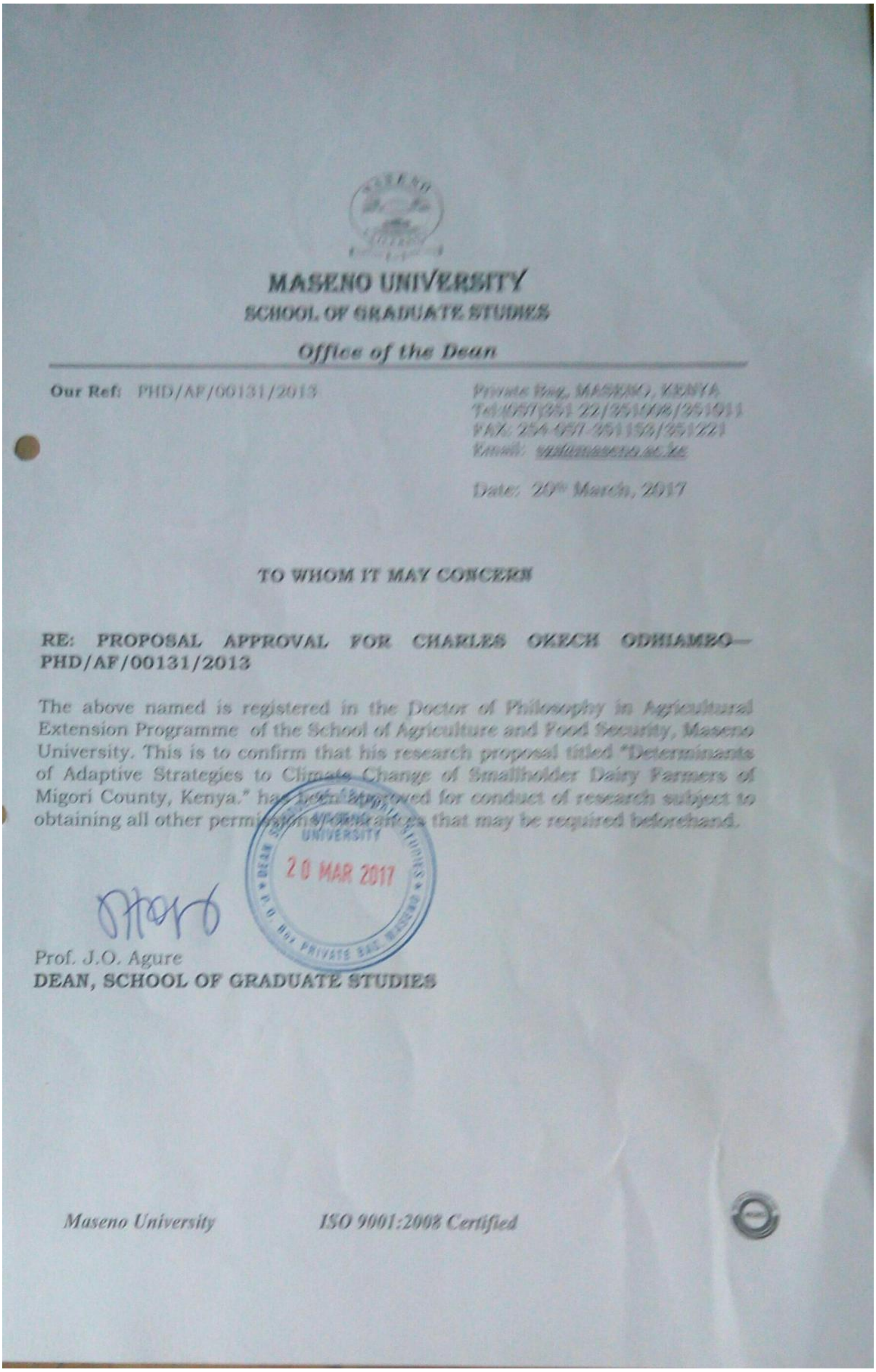
6. Establish **lessons learnt** from the **responses** to **climate change effects** in Migori County and its environs *(Documentary evidence, quoting source, author, and date).*

7. Establish **key recommendations** made by key stakeholders on **how best to deal with the effects of climate change** in Migori County and its environs in future *(Documentary evidence, quoting source, author, and date).*

C. Ministry of Agriculture, Livestock and Fisheries/KALRO

1. Seek to have a documentary understanding of the **impact** of **climate change** in Migori County and its environs on:
   a) Water availability for livestock;
   b) Availability of feeds (forage) for livestock;
   c) The prevalence of livestock diseases and parasites;
   d) Milk (and meat) production from cattle (dairy and beef);
   e) Calving intervals and calf health.
2. Seek to have a documentary evidence of the **implications** of the **climate change effects** (impact) on **livestock** in Migori County and its environs in terms of:
   a) **Type of farming** the farmers opt for (especially the smallholder farmers);
   b) The **system of rearing dairy cattle** chosen by smallholder dairy farmers in the County;
   c) The **breeds of dairy cattle** chosen by smallholder dairy farmers in the County;
   d) The **number of dairy cattle kept** by smallholder dairy farmers in the County;
   e) The **labour requirement** for running smallholder dairy farming enterprise in the County;
   f) The **choice of feeds** for smallholder dairy enterprise in the County;
   g) The **housing requirements** for smallholder dairy enterprise in the County;
   h) The **cost of running a smallholder dairy enterprise** in the County.
3. Seek to establish:
   a) **Sources of information** to smallholder dairy farmers regarding climate change and its effects;
   b) Smallholder dairy farmers' **contacts with extension** (types and frequency of contact);
   c) Smallholder dairy farmers' **linkages with research** (types and frequency of linkage);
   d) Smallholder dairy farmers' **support to access markets and market information**;
   e) Smallholder dairy farmers' **support to access credit and financial services** (Sources and types).
4. Seek to establish **challenges/gaps** faced by the Ministry/KALRO in trying to reach to the smallholder dairy farmers in the County and its environs *(Documentary evidence, quoting source, author, and date).*
5. Seek to understand suggested **measures to address** some of the **challenges/gaps** identified *(Documentary evidence, quoting source, author, and date).*

APPENDIX IX: SCHOOL OF GRADUATE STUDIES APPROVAL OF PROPOSAL FOR DATA COLLECTION



MASENO UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Office of the Dean

Our Ref: PHD/AF/00131/2013

Private Bag, MASENO, KENYA
Tel:(057)351 22/351008/351011
FAX: 254-057-351153/351221
Email: sgs@maseno.ac.ke

Date: 20th March, 2017

TO WHOM IT MAY CONCERN

RE: PROPOSAL APPROVAL FOR CHARLES OKECH ODHIAMBO— PHD/AF/00131/2013

The above named is registered in the Doctor of Philosophy in Agricultural Extension Programme of the School of Agriculture and Food Security, Maseno University. This is to confirm that his research proposal titled "Determinants of Adaptive Strategies to Climate Change of Smallholder Dairy Farmers of Migori County, Kenya." has been approved for conduct of research subject to obtaining all other permissions/clearances that may be required beforehand.

DEAN SCHOOL OF GRADUATE STUDIES MASENO UNIVERSITY 20 MAR 2017 P.O. Box Private Bag MASENO

Prof. J.O. Agure
DEAN, SCHOOL OF GRADUATE STUDIES

Maseno University *ISO 9001:2008 Certified*

APPENDIX X: ETHICAL APPROVAL LETTER-MASENO UNIVERSITY

MASENO UNIVERSITY ETHICS REVIEW COMMITTEE

Tel: +254 057 351 622 Ext: 3050
Fax: +254 057 351 221

Private Bag – 40105, Maseno, Kenya
Email: muerc-secretariate@maseno.ac.ke

FROM: Secretary - MUERC

DATE: 4th April, 2017

TO: Charles Okech Odhiambo
PG/PhD/AF/00131/2013
Department of Agricultural Economics and Rural Development
School of Agriculture and Food Security
Maseno University
P. O. Box, Private Bag
Maseno, Kenya

REF: MSU/DRPI/MUERC/00387/17

RE: Determinants of Adoptive Strategies to Climate Change of Smallholder Diary Farmers of Migori County, Kenya. Proposal Reference Number MSU/DRPI/MUERC/00387/17

This is to inform you that the Maseno University Ethics Review Committee (MUERC) determined that the ethics issues raised at the initial review were adequately addressed in the revised proposal. Consequently, the study is granted approval for implementation effective this 4th day of April, 2017 for a period of one (1) year.

Please note that authorization to conduct this study will automatically expire on 3rd April, 2018. If you plan to continue with the study beyond this date, please submit an application for continuation approval to the MUERC Secretariat by 4th March, 2018.

Approval for continuation of the study will be subject to successful submission of an annual progress report that is to reach the MUERC Secretariat by 4th March, 2018.

Please note that any unanticipated problems resulting from the conduct of this study must be reported to MUERC. You are required to submit any proposed changes to this study to MUERC for review and approval prior to initiation. Please advice MUERC when the study is completed or discontinued.

Thank you.

DIRECTORATE OF RESEARCH PUBLICATION & CONSULTANCIES
MASENO UNIVERSITY

Dr. Bonuke Anyona,
Secretary,
Maseno University Ethics Review Committee.

Cc: Chairman,
Maseno University Ethics Review Committee.

MASENO UNIVERSITY IS ISO 9001:2008 CERTIFIED

APPENDIX XI: NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION (NACOSTI RESEARCH AUTHORIZATION LETTER

NATIONAL COMMISSION FORSCIENCE, TECHNOLOGY ANDINNOVATION

Telephone: +254-20-2213471, 2241349,3310571,2219420
Fax: +254-20-318245,318249
Email: dg@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

[illegible]
[illegible]
P.O. Box [illegible]
NAIROBI-KENYA

Ref. No. **NACOSTI/P/17/28918/17301**

Date: **14th June, 2017**

Charles Okech Odhiambo
Maseno University
Private Bag
MASENO.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Determinants of adaptive strategies to climate change of smallholder dairy farmers of Migori County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Migori County** for the period ending **13th June, 2018.**

You are advised to report to **the County Commissioner and the County Director of Education, Migori County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

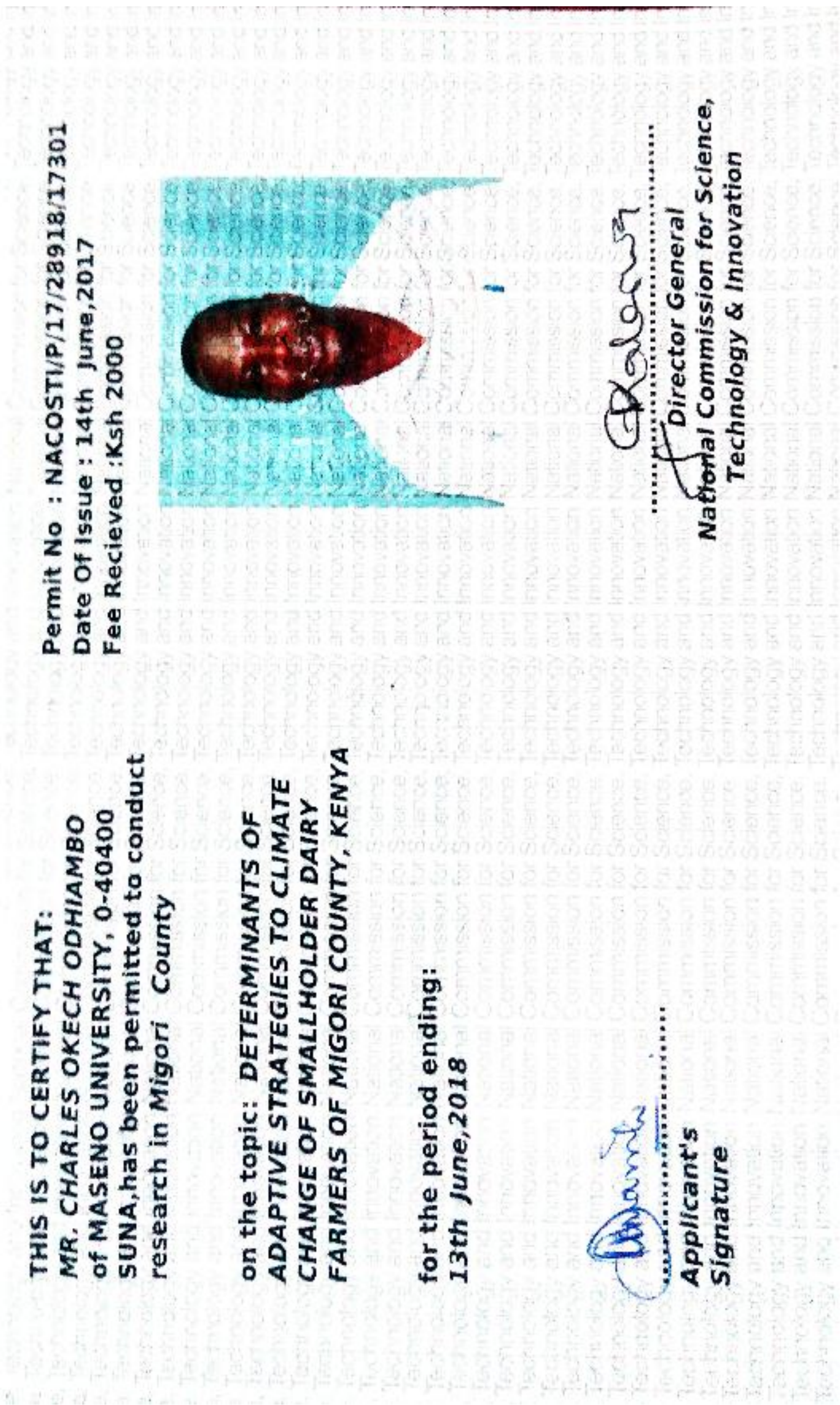
GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Migori County.

The County Director of Education
Migori County.

APPENDIX XII: NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION (NACOSTI) RESEARCH PERMIT



THIS IS TO CERTIFY THAT:
MR. CHARLES OKECH ODHIAMBO
of MASENO UNIVERSITY, 0-40400
SUNA,has been permitted to conduct
research in *Migori County*

on the topic: ***DETERMINANTS OF ADAPTIVE STRATEGIES TO CLIMATE CHANGE OF SMALLHOLDER DAIRY FARMERS OF MIGORI COUNTY, KENYA***

for the period ending:
13th June,2018

....
Applicant's Signature

Permit No : NACOSTI/P/17/28918/17301
Date Of Issue : 14th June,2017
Fee Recieved :Ksh 2000

....
Director General
National Commission for Science, Technology & Innovation